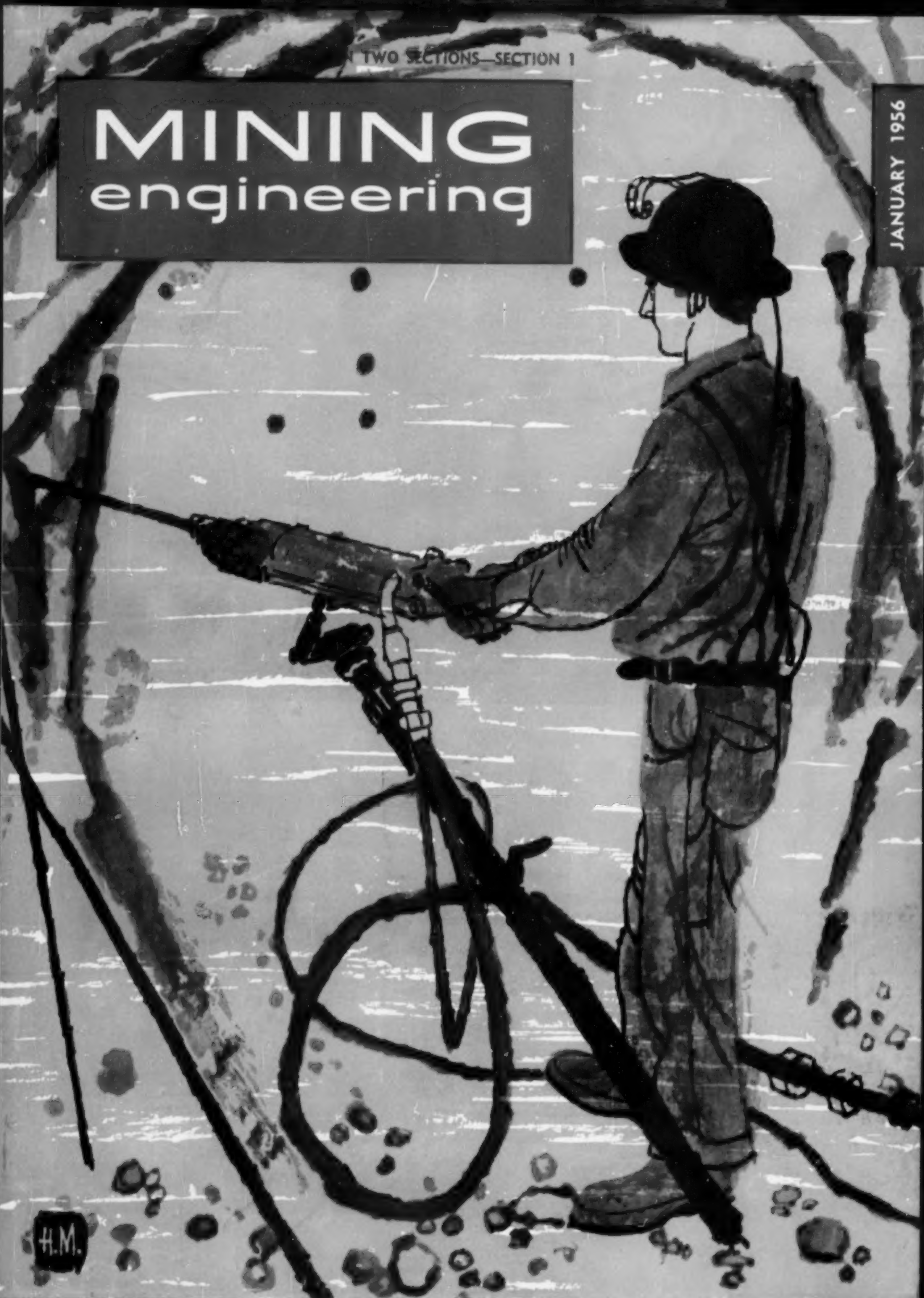
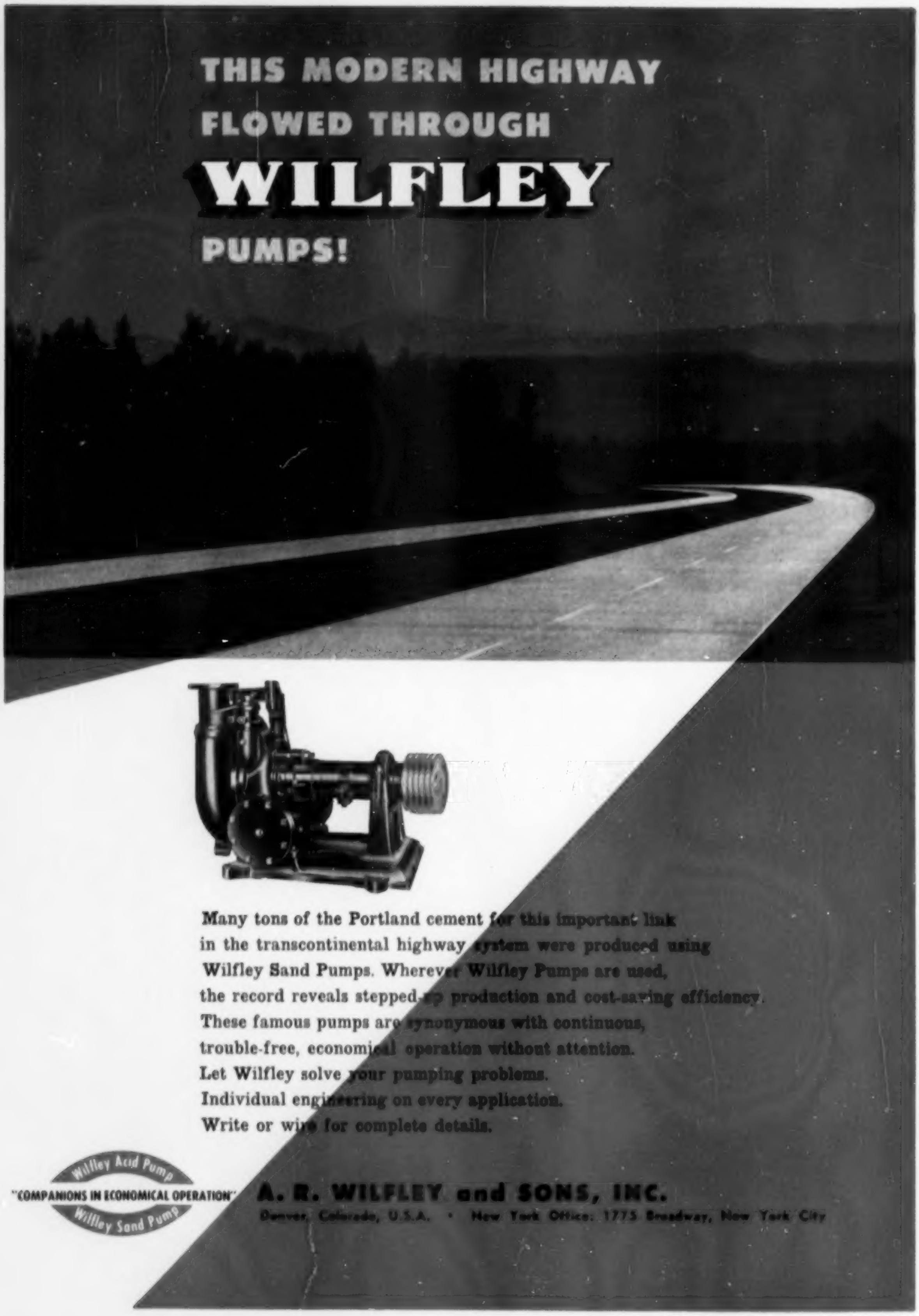
N TWO SECTIONS—SECTION 1

MINING engineering

JANUARY 1956





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PUMPS!
Many tons of the Portland cement for this important link in the transcontinental highway system were produced using Wilfley Sand Pumps. Wherever Wilfley Pumps are used, the record reveals stepped-up production and cost-saving efficiency. These famous pumps are synonymous with continuous, trouble-free, economical operation without attention.
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"COMPANIONS IN ECONOMICAL OPERATION"
Wilfley Sand Pump
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MINING engineering

VOL. 8 NO. 1 JANUARY 1956

In Two Sections—Section I (Index is Section II)

COVER

Cover by Herb McClure. Whatever 1956 brings, finding new ore will be more difficult, require more ingenuity, and be more costly. S. S. Clarke and D. C. Brockie's article beginning on page 27 discusses a method that may help in that ore search, the application of the jackleg drill to local exploration.

FEATURES

ARTICLES

TRANSACTIONS

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $10 foreign; $6 for AIME members, or $4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies $.75; single copies foreign $1.00, special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publications.

Registered cable address, AIME, New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC.

PERSONNEL

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18**; 100 Farnsworth Ave., **Detroit**; 57 Post St., **San Francisco**; 84 E. Randolph St., **Chicago 1**. Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Chief Engineer, 6 years with major aluminum producer's bauxite quarry operations in South America, managerial and consulting experience, mining graduate 1937, multilingual. Previously engaged gold dredging, nonferrous metallurgy, rockwool manufacture. Available for foreign or stateside assignment May 1956. M-250.

POSITIONS OPEN

Mining Engineer, young, with coal mining training. Excellent opportunities for well qualified engineer for growing coal mining organization. Location, Alabama. W2139.

Mining or Metallurgical Engineer, young, for laboratory, mill and field duties. Salary, $5400 a year. Location, Chile. F2582(a).

Mining Engineers. (a) Shift Boss for underground mine. Two to 3 years experience. Salary, $4200 a year plus $50 a month production bonus. (b) Mining Engineer, recent graduate, or equivalent, for underground mine. Spanish not necessary. Salary, $4200 a year plus housing and $75 a month allowance. Location for (a) and (b) South America. (c) Assayer with some experience for Newfoundland. Salary open. Housing available. W2601.

Equipment Supervisor, preferably with engineering training and plant engineering experience covering maintenance of mining equipment. Salary, $6000 to $6500 a year. Location, South. W1772.

Field Engineer, E.M. or geology degree, 28 to 35, to supervise three or four drilling crews of native laborers and foremen on an exploration assignment. Must have had at least 2 years experience in field exploration work including mapping and drilling. Salary, $6400 to $8430 per year plus 20 pct plus $50.00 a month for housing. Headquarters, California. C4196.

Chemical Mineralogist, well trained in mineralogy and related subjects, preferably with good background in chemistry, to identify and report on minerals, rocks, and ores; to conduct or to direct assistant in making assays for gold, silver, copper, lead, and other elements of commercial importance; to prepare and publish results of studies on minerals. Must be U. S. citizen or have declared intentions of becoming one. Salary, $4800 to $5800 a year. Location, Nevada. W2092.

Mining Engineer, young, with underground experience, for surveying, mapping, etc. with metal mining company. Salary open. Location, South. W1725.

Chief Geologist to take charge of an exploration department. Should have 15 to 25 years experience in field exploration and mine examination including experience in economic analysis and evaluation of mines, properties, and prospects. Oil and gas geological experience desirable. Traveling in U. S., Canada, and Alaska. Salary open. References required. Headquarters, New York, N. Y. W2219.

Mining Superintendent for small tungsten mine operation in New Mexico. Salary, $6000 to $7200 a year. W2565.

Construction Engineer with civil or mining engineering training and tunnel experience, to supervise line and grade, check quantities, and do project engineering. Salary, $8400 a year minimum. Location, western Pennsylvania. W2220.CH.

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SALES ENGINEER

Leading manufacturer of machinery located in Milwaukee, Wisconsin area has opening for Sales Engineer, 30 to 40 years of age, who has had several years experience in sales of heavy machinery. Must have degree in mechanical or mining engineering. This represents an exceptionally fine opportunity which should lead to administrative responsibilities for right man. Write, stating age, education, experience, present employment, personal data and salary expected to start. Replies strictly confidential.

Reply Box 3-A AIME

29 West 39th St. New York 18

POSITION VACANT

Wanted: Graduate engineer to fill vacancy in Engineering Department of large coal mining operation. Must be qualified for underground and surface surveying, mapping, and general drafting work and must be capable of designing simple structures. Man with experience preferred.

Apply: **INLAND STEEL COMPANY**
Wheelwright, Kentucky

Technical Editor Wanted

Open at AIME headquarters is a position for a young engineer to do editorial work on the JOURNAL OF METALS. A man is desired with educational background and experience from the fields of iron and steel, extractive metallurgy, and physical metallurgy. The primary qualification, other than a degree in one of the above fields and a minimum of 2 years experience in the minerals industries, is an aptitude for editing and writing. Applicants should apply to: Editorial Director, AIME, 29 W. 39th St., New York 18, N. Y., sending experience records, references, photograph, and any special qualifications for the job. Date of availability and salary requirements should be stated.

AMERICAN COMPANY WITH NON-FERROUS MINING OPERATIONS IN SOUTH AMERICA is interested in engaging the following:

Junior Mining Engineer
Bachelors Degree
Single

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Bachelors Degree
Single

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Bachelors Degree
Single

Civil Engineer
Bachelors Degree
Single

Geologist
Doctors Degree
Single

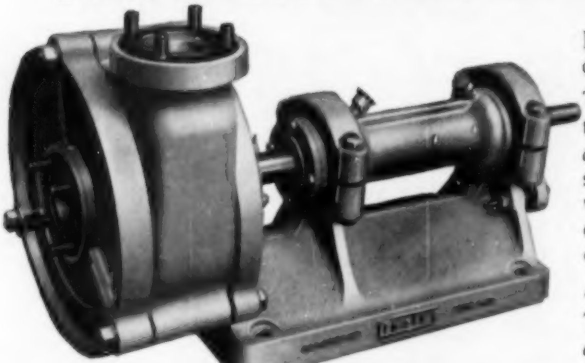
Smelter Foreman
Single or Married

Mining Engineer: To assist in organizing or planning mine engineering work including calculating, drafting, underground and surfacing surveying, safety and ventilation planning.
Single or Married.

Employment based on three-year contract. Company pays transportation, packing and provides housing, insurance and other benefits. For married men with children the company provides educational facilities.

Box 4-A AIME 29 West 39th St., New York 18

"Acettaremos una Gruesa"



In the Argentine it means "we'll take a gross". In this case a gross of Linatex Sand Pumps.

The Argentine needed a large number of pumps to meet the growing demands of their Mining Industry. Not just *any* pumps, but installations that could handle abrasive slurries without wearing out; that could pump sand and water with a maximum of 20% solids by volume at 25 cubic metres per hour against a total manometric head of 24 metres.

A gross of *Linatex* pumps were ordered.

That's a big order—and a sound vote of confidence, in *any* language.

The LINATEX Pump—*the most lasting pump in the world*

6 of the 15 Linatex factories in the world
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Australia	U.S.A.
Linatex (Australia) Pty. Ltd., David Street, Dandenong, Victoria, Australia	Linatex Corporation of America, Vernon Avenue, Rockville, Conn., U.S.A.

Canada	England	Malaya	South Africa
Wilkinson Linatex Co. Ltd., 2210 Parthenais St., Montreal 24, Quebec, Canada	Wilkinson Rubber Linatex Ltd., Camberley, Surrey, Gt. Britain	The Wilkinson Process Rubber Co. Ltd., 96 Ampang Road, Kuala Lumpur, Fed. of Malaya	R. J. Spargo Ltd., P.O. Box 7128, Johannesburg, S. Africa

P.18(M)

BOOKS

Please Order These Publications from the Publishers

1954 Census of Mineral Industries—Preliminary Reports, *Bureau of the Census,* Washington 25, D. C.—Preliminary statistics on shipments of mineral products; value added in mineral production; the number of employes; wages, salaries, cost of supplies and materials, fuels, purchased electric energy, and contract work; capital expenditures; horsepower rating of power equipment; and water intake. An advance announcement and order form, Comm-DC 16255, lists 34 reports at 10¢ or 20¢ apiece. The complete series costs $2.25. Orders also may be sent to any U. S. Department of Commerce Field Office.

Industrial Ventilation, A Manual of Recommended Practice, *American Conference of Governmental Industrial Hygienists,* Committee on Industrial Ventilation, P.O. Box 453, Lansing, Mich., $3.00, various paging, 11x8½ in., spiral binding, 1954.—The purpose of this manual is to meet the needs of official industrial hygiene agencies for a ready single source of recent data on industrial exhaust ventilation, for standardizing ventilation practices, and for training purposes. The many sketches, graphs, and data tables make the manual useful for anyone, such as the plant engineer, who must deal with ventilation problems.

Geology of Cathedral Mountain Quadrangle, Brewster County, Texas, by William N. McAnulty, *Bureau of Economic Geology,* University of Texas, Austin 12, Texas, $1.00, 48 pp., 3 fig., 2 heliotype plates, geologic map in color, 1955.—Reprinted from *Bulletin of the Geological Society of America,* Vol. 66, No. 5, May 1955. This quadrangle is in the southeastern Davis Mountains of Trans-Pecos, Texas. Extra copies of the geologic map are available at 25¢ each.

Geologic Guidebook Along Highway 49, Sierran Gold Belt—The Mother Lode Country, *California Div. of Mines,* Ferry Bldg., San Francisco 11, Calif., Bulletin 141, $1.50 plus 3 pct sales tax, 4th Edition, 1955.—Highway 49 runs for 277 miles from Mariposa in the south to Sattley in the north. First published in 1948, this is a semitechnical guide to the mines, minerals, and rocks of the region, and historic structures. Among the ten authors contributing to the text are Olaf P. Jenkins with "Sierra Nevada Province" and the "Geological History of the Sierran Gold Belt," and C. A. Logan with a "History of Mining and Milling Methods in California." There are a series of geologic maps and 8 colored and 231 black and white photographs.

Engineering Standards Multiple V-Belt Drives, *Rubber Manufacturers' Assn. Inc.,* 444 Madison Ave., New York 22, N. Y., or *Multiple V-Belt Drive & Mechanical Power Transmission Assn.,* 27 E. Monroe St., Chicago 3, Ill., $1.00, 24 pp., September 1955.—This manual was first published in 1951. Basic changes include ten pages of new horsepower ratings. These in general give increased ratings for quality belts throughout the generally accepted speed range. For the first time ratings on premium quality belts are also included. Ratings are shown for belt speeds from 200 to 6000 fpm.

Geology of the Elkhorn Ranch Area, Billings and Golden Valley Counties, North Dakota, by Bernold M. Hanson, Report of Investigations 18, *North Dakota Geological Survey,* Grand Forks, N. D., $1.00, map sheet, 1955.—This area lies in the most rugged part of the North Dakota Badlands. "Although the presence of coal was long known . . . the lack of commercial beds made the area unattractive for mining, hence it was slighted geologically until the discovery of oil in the Williston Basin. The ranchers mine the lignite for their own use."

LETTERS

Sirs:

The other night I finished rereading *Applied Geophysics in the Search for Minerals* by A. S. Eve and D. A. Keys.* I can think of no better summary for this fourth edition than that the clear, concise, well written volume is too light for the professional geophysicist and too heavy for the amateur, but it impresses me as being the best introduction for a student in the complex science of applied geophysics.

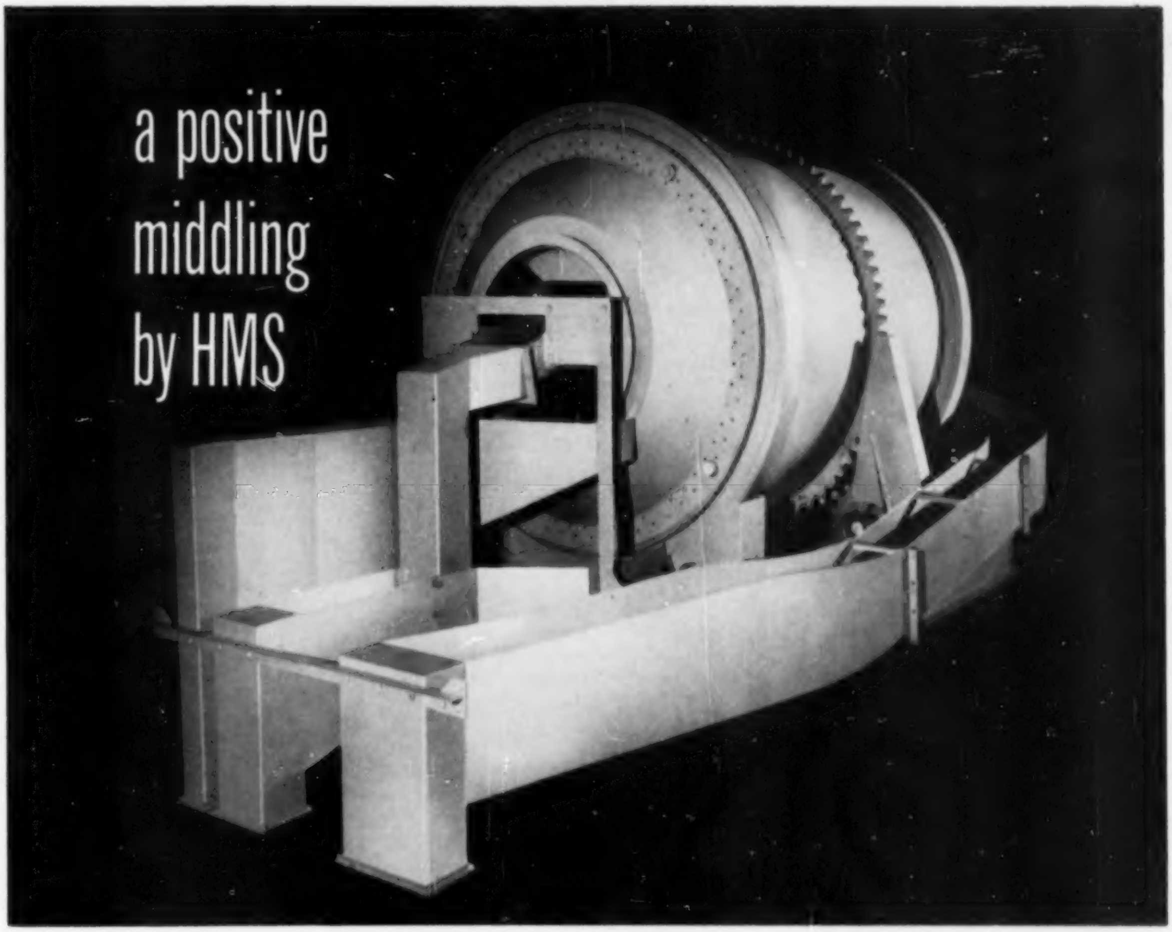
The principal additions consist of sections on airborne instruments, amplification of radioactive and well logging methods, less common applications, and the appendices. The bibliography, although short, is exceptionally well chosen.

If I were making a curriculum, this edition would form the foundation of a semester course in undergraduate applied geophysics. The other half would be devoted to more theoretical aspects. Therein I would discuss those parts of the fluid and the solid earth that find no place in applications to the search for fuels or minerals.

As early as 1935, Gerald R. McCarthy and I began using sandbox experiments in geophysical instruction. I am, therefore, glad to note their inclusion in this particular edition of Eve and Keys.

H. W. Straley, III

* *Cambridge University Press,* $7.50, 382 pp., 4th edition, 1955.



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With Wemco's Two Compartment Drum Separator, a successful middling product from HMS is not just a shakey promise — it's a sure thing. Use of two different separating gravities is the right way to do the job *when you eliminate cumbersome duplicate equipment.* Wemco has developed a two gravity technique that uses little more equipment than a single stage.

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2. **YOU REDUCE THE TAILINGS** because the other separating gravity bath is independent and can be selected to keep all the remaining values in the middling for reprocessing.
3. **YOU PROFIT BY THE MIDDLINGS** because by recrushing you can save much that otherwise would be lost.

Wemco's positive two stage heavy media separation method is fully explained in available literature. To learn what this can do for your plant, write today for your copy.

Representatives in principal cities of the United States and Canada and in major countries throughout the world.

1955 has been a year of change, consolidation and progress in both a corporate and a technical sense for Dorr-Oliver. Just a year ago we were deeply involved in the complexities of merger and, as we near the end of this first year of combined operations, a review has more than the usual significance.

Perhaps most notable has been the remarkable integration of our combined staff and its growing effectiveness in every area of operation. With this integration came important organizational change — the creation of new groups to handle technical problems more effectively and to explore new opportunities. With it also has come the strengthening of sales staff in some areas and the opening of new offices in others, designed to provide better service to our clients and customers.

Of the utmost importance in this rapidly developing picture is the welcoming of Dorr-Oliver-Long Limited as a full member of the worldwide D-O family. The natural result of a close and friendly relationship dating back to 1911, the consolidation of our Canadian operations with those of E. Long Limited of Orillia on January 1, 1956, will unquestionably strengthen our overall operations.

PULP AND PAPER — In 1955, field testing and subsequent commercial acceptance of the Webwelder for splicing corrugating medium and other heavy grades of paper was among our most significant projects. Contributing heavily to our volume of business were new or expanded Recausticizing Systems in the Pacific Northwest, Southeast, Canada, India, Sweden, Finland, Mexico and Chile. Next year the Horizontal Filter, already used for washing cotton linters, will be applied to pulp washing in a Southern mill.

INDUSTRIAL WASTES — Also in the pulp and paper industry, the largest biological kraft mill waste treatment plant in the world went into operation at West Virginia Pulp and Paper Company's Covington, Virginia, mill. And on the West Coast the most comprehensive treatment plant ever designed is now on stream handling wastes from an oil refinery. Both are D-O equipped. Orders were placed for waste treatment units to serve a midwest cannery and a large Eastern photographic equipment manufacturer.

PETROLEUM — The newly introduced D-Sander has proved to be extremely successful in removing sand from rotary drilling mud and has been widely utilized in the Gulf Coast oil fields. Fabrication of the longest petroleum filters ever constructed — six 10′ x 22′3″ Olivers for dewaxing — was completed at our Hazleton shops. Research and development continued on a new and unusual type of hydrocarbon purification unit, the applications of which appear almost boundless in the petroleum industry.

URANIUM — During the year a large D-O equipped Canadian uranium mill went into operation and orders were received for processing equipment to be used at six other United States and Canadian mills now under construction or being expanded. Facilities at our Westport laboratories have been enlarged to handle all types of uranium extraction work and to process small quantities of material from ore through "yellow cake". In a closely related project — the production of rare earths — D-O equipment will be widely utilized in a plant under construction.

SUGAR — As a result of three years of development we have introduced the RapiDorr Cane Juice Clarifier designed with 30% less volume than conventional units. A number of these machines will be in operation in the coming 1956 campaigns. Our associates in Italy have sold two Continuous Carbonation Systems for beet sugar processing on the Italian peninsula and mills in India will clarify cane juice in units manufactured by D-O GmbH in Wiesbaden.

SANITATION — The Densludge Process of prethickening sludge is now operating at two full-scale Biofiltration plants in the Southwest with general improvement in overall plant performance an unexpected result of its use. Tests have been virtually completed on a new Degritting Clarifier to be placed on the market in the near future. The Refuse Treator, which was developed in Holland and which may soon become an integral part of the domestic D-O line, gives the sanitary engineer another tool for the accomplishment of his ultimate goal.

RESEARCH AND DEVELOPMENT — Fundamental research has continued on the unit operations basic to D-O equipment. While such work is necessarily of a long range nature, increased fundamental knowledge has already led to marked advances in the field of clarification.

In addition to improvement of basic units, the company is constantly investigating new lines which can be profitably integrated with our other business. Current projects include an investigation to determine the manner in which D-O can make further contributions to the Atomic Energy Program and development of an ingenious Dutch device for fine screening.

COPPER — Half a world apart — in Israel and Arizona — two D-O designed copper ore dressing plants, one a full-scale operation and the other a pilot plant, are now under construction. In the United States, three large concentrators in the Southwest ordered equipment for plant expansions and in the Belgian Congo the first FluoSolids System to roast copper concentrates prior to electrolytic recovery went into operation.

FERTILIZER — Missouri Farmers Association's new plant, proving ground for the Diammonium Phosphate Process, attained design capacity in record time at Joplin, Missouri. Utilization of this new process makes commercial production of unusually high analysis fertilizer from concentrated phosphoric acid possible for the first time. In Japan, two more D-O designed fertilizer plants went into operation and a third was under construction in Norway.

WATER TREATMENT — In the field of water purification, Caracas, Venezuela and Kansas City, Missouri have duplicated orders of previous years for plant expansions and new facilities now under construction in both India and Turkey will employ extensive D-O equipment. First installations of the PeriFilter System, introduced two years ago, have shown marked economies of construction and unusual adaptability to small plants.

STARCH — Following the example of current practice in the Netherlands where the DorrClone was developed, five starch processing companies in other parts of the world ordered DorrClone Systems for their operations. Starch Washing Systems — each the first of its type in the various countries — will be installed in Brazil, Canada, Scotland and the United States. A fifth producer will use TM DorrClones to recover solids from starch washing filtrate in the U. S.

FLUOSOLIDS — Most significant achievement in the field of fluidization was the successful commercial demonstration of the first FluoSolids Coal Dryer. Equally adaptable to the drying of either metallurgical or steam coal, this unit will handle material as coarse as 1½″ with ease. During the year two other "firsts" were recorded — the first FluoSolids System went into operation in the Philippines and the first purchased for use in Germany. Repeat orders were received from companies in South Africa, Canada, Italy and Japan, and in the U. S. a large copper producer ordered its fourth complete System and seventh individual Reactor.

CHEMICAL — Expansion plans for alumina processing facilities in Jamaica and Germany, a potash counter-current decantation system in New Mexico, and new brine purification and pigment plants in the U. S. all incorporated substantial amounts of Dorr-Oliver equipment in their flowsheets.

Any pride we may feel in the events and accomplishments of the year is shadowed by the sudden passing of one of our Founder-Chairmen, Edwin Letts Oliver, late in the summer just past. His mechanical genius, strength and human warmth will be deeply missed by the engineering fraternity of the world. To Dorr-Oliver, and to those of us who knew him well, his loss is irreparable.

For the future, our resources are considerable. The initial enthusiasm and resourcefulness of our staff, the promise of new developments and the strength and solidarity of our Associates in Canada and abroad — all point to a steadily increasing ability to serve and an eventful year ahead.

J. D. Aitchison Jr.

Stamford, Conn., U.S.A.

Manufacturers News

News
Equipment
Catalogs

• FILL OUT THE CARD FOR MORE INFORMATION •

Safety Floodlight

Compressed air turbo-generators power this 22-lb explosion-proof floodlight designed for use in mining, refining, and other industrial

activities where electric power is not available. Introduced by *Copco Eastern Ltd.*, the 150-w, 12-v lamp draws 23 cfm of air at pressures ranging from 60 to 100 psi. **Circle No. 1.**

Earthmover Dump

When the *Kenworth Motor Truck Corp.* 802-B dumps, the entire trailer rises and the rear trailer wheels move forward to a position directly behind the tractor tires. Powered by a 300-hp turbocharged Cummins NRT-600 diesel engine, truck-tractor

has 32-cu yd struck capacity and weighs 165,000 lb. A special guide and equalizer stabilizes the body when dumping, so that there is no strain or twist on the twin three-stage telescopic hoist. **Circle No. 2.**

Air Filtration

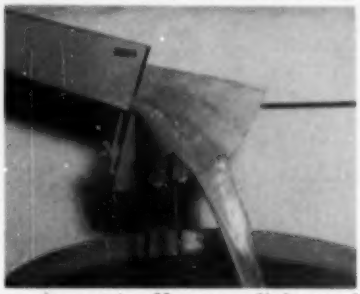
In an installation employing Ultra-filtration having a design volume of 720,000 cfm of city air, *Wheelabrator Corp.* process reduces dust content from 5.21 to 0.04 mg per 1000 cu. ft. Process, claimed to be moderate in cost and nearly free from maintenance expense, uses filter bags charged with a filter aid to precoat the filtering surfaces. **Circle No. 3.**

Reverse-Lay Aerial Cable

Anaconda Wire & Cable Co. has a reverse-lay pre-assembled aerial cable with AB butyl rubber insulation and neoprene jacket. Conductors of the self-supporting cable are assembled in a series of reverse twists regularly spaced along cable. Taps can be made easily, as lineman can untwist or separate conductors at any point. On nonshielded cable, taps can be made on energized line. **Circle No. 4.**

Fanning Concentrator

Carpco concentrator may open up new fields in wet separation of minerals. The simple gravity device is lightweight, compact, and without



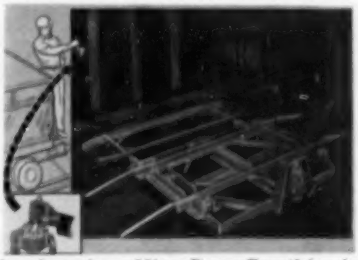
moving parts. Neoprene lining and outside coatings resist abrasion. Dilution of pulp required is said to be low. A laboratory test unit is available. **Circle No. 5.**

Motor Grader

Sitting or standing, the operator has a full view of the job being done with *Allis-Chalmers'* Forty-five motor grader. Heavy duty unit weighs 23,800 lb with 17,375 lb on tandem drive rear wheels and 6,425 lb on front wheels. Blade pressure is 10,950 lb. Six-cylinder, 4-cycle diesel engine delivers power for forward speed to 20.6 mph and 7 mph in reverse. **Circle No. 6.**

Easy Does It!

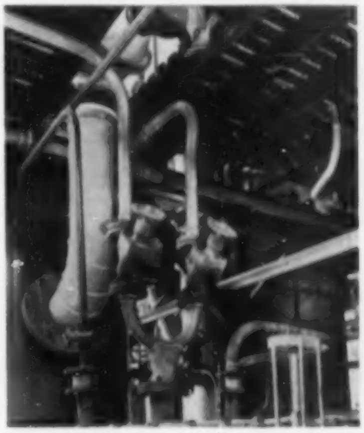
With the Canton air power car transfer, one man does the work of three and at least 50 pct faster. Made



by *American Mine Door Co.*, this air mechanism is claimed to transfer a 6-ton load by a mere flip of a switch handle. **Circle No. 7.**

Plastic Pipe

A fire and chemical resistant rigid PVC plastic pipe, marketed by *Joseph T. Ryerson & Son*, can be sawed, threaded, solvent welded, and heat welded. Ryertex-Omicron



PVC pipe has no additives or fillers, which insures maximum resistance to attack by various acids, alkalies, salt solutions, alcohols, and other chemicals. It is shown here as installed in a chlorine drying and liquefaction plant. **Circle No. 8.**

Twin Roll Crusher

Pioneer Eng. Works has a new 30x24-in. twin roll crusher said to increase production 33 1/3 pct without corresponding hike in cost. Hydraulic jack and shim adjustment mechanism makes changing the roll setting a simpler job. Capacity runs up to 254 tons of $-2\frac{1}{4}$-in. aggregate per hr with material weighing 2700 lb per cu yd. **Circle No. 9.**

News and Notes

Construction has begun on the main plant for *Houston Technical Laboratories*, Texas Instruments geophysical instrumentation subsidiary. The 40,000-sq ft building is being built on a 5-acre tract on Buffalo Speedway in Houston . . . . *Harnischfeger International Corp.* has arranged with *Kobe Steel Works Ltd.* for the production in Japan of P&H shovels and truck cranes. Kobe Steel production will serve markets in the Far East, South East Asia, and South Sea Island . . . . *Thor Power Tool Co.*, Aurora, Ill., has formed a Construction Equipment Div. This autonomous unit will supplement Thor's present line of air and electric tools . . . . *Pennsylvania Salt Mfg. Co.*, Philadelphia, has appointed *Osmose Wood Preserving Co. of America Inc.*, Buffalo, as exclusive U. S. sales outlet for Pennsalt line of neoprene products.

(21) THICKENERS, CLARIFIERS, AGITATORS: Sixteen-page bulletin 31-E from *Hardinge Co.* covers equipment for mining, chemical, metallurgical, and other industrial processing operations in which separation of solids from a liquid is required. Catalog discusses applications, shows construction details, and has a formula for determining tank diameters of thickeners for any given set of data.

(22) AERO & GROUND MAGNETIC INTERPRETATION: Simple operation, versatility, and portability are features of the *Geophysical Specialties Co.* magnetic susceptibility bridge. Rock sample may be in form of drill core, chips, fragments, or powder. Sample holder will take AX core directly and EX core in a lucite sleeve included with the instrument.

(23) GRAVITY CONCENTRATION: *Denver Eqpt. Co* has a bulletin on low-cost gravity concentration of fine as well as coarse minerals. Facts are given on Denver selective mineral jigs designed to handle unclassified, unsized feed. Discussed are precision separation, minimum maintenance, reduction of screen blinding, and low water and low hp requirements.

(24) FACTS & FIGURES: Conveniently indexed, the 96-page pocket reference from *Pioneer Engineering Works* contains metric-U. S. conversion factors, decimal equivalents of fractions, dumping angles, crusher settings, feeder capacities, tank capacities, and other miscellaneous information.

(25) BIG SHOVEL, LOW COSTS: *Harnischfeger Corp.* has a certified report on a New York contractor's experience with a P&H 1055 shovel. He explains that his costs during the first months of operation opened his eyes to the increased economy of a big 3½-yd shovel.

(26) WIRE ROPE BLOCKS: Bulletin 163 shows features of *Sauerman Bros.* Durolite blocks in sizes from 6 to 42 in. New rigger's block has an extra wide sheave groove that permits use of larger cable than the standard block of the same diameter.

(27) BELT CONVEYOR IDLERS: *E. F. Marsh Eng. Co.* has a catalog with essential information on the selection, application, and mounting of its line of belt conveyor idlers. Specifications are included for practically every idler in the bulk handling field.

(28) ROCK DRILLS: *Syntron Co.* has a bulletin on self-contained gasoline powered rock drills. Unaffected by climatic conditions these portable drills will clean out 1 3/16-in. diam holes to a depth of 13 ft.

(29) MATERIAL HANDLING: *Caterpillar Tractor Co.* has a booklet on handling materials at low cost. On-the-job photographs show Cat machines stockpiling carbon, harvesting salt, recovering scrap steel from hot slag, and doing many other jobs "with maximum profits for their owners."

(30) PIPING: Brochure illustrates *Mercury Piping Co.* operations in fabrication and erection of low and high pressure piping. These range from pneumatic control panel system to the largest hydraulic presses in the world.

Free Literature

(31) MAGNETIC PLATES: Used in processing aggregates, minerals, metals, sand, and coal, *Homer Mfg. Co.* permanent magnetic plates automatically and economically remove tramp iron. Bulletin PL-250 includes application diagrams and performance data.

(32) COLLOIDS: Four-page booklet from *Acheson Colloids Co.* lists 42 colloidal and semicolloidal dispersions for operational functions, maintenance, lubrication, machine design, and other industrial applications. Carriers and diluents are given for each product along with typical applications and important physical data.

(33) TUBING: Folder from Tubular Products Div., *Babcock & Wilcox Co.* contains a complete listing and a description of available technical literature on tubing. Also shown are chemical analyses, physical properties, mechanical properties, and creep strength of 20 steels.

(34) U PROSPECTING: Portable Geiger counter made by *Nuclear Instrument & Chemical Corp.* features a sensitive probe that may be mounted in unit handle or removed for surveying crevices, drillholes, and cave walls. Three ranges cover intensities of 0.2, 2, and 20 mr/hr full scale, corresponding to 600, 6000, and 60,000 counts per min.

(35) ROTARY DRILL: *Davey Compressor Co.* has an illustrated bulletin on the model M-8A rotary drill. Greater speed in many formations is due to the high uphole velocity of the air used to remove cuttings. Bit life is increased since hole bottom is clean and free from abrasive bit wearing cuttings.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Apr. 15, 1956—if mailed in U. S. or Canada.

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
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51	52	53	54	55	56	57	58	59	60
61	62	63	Students should write direct to manufacturer.						

Name..Title..............

Company..

Street..

City and Zone..State..............

(36) CHLORINATOR: Catalog 70-10 from *Fischer & Porter Co.* illustrates the F&P 1050A chlorinator for purifying water supplies, treating sewage and industrial wastes, and controlling slime. Multicolored flow diagram shows how chlorine gas and water are kept separate until they reach the ejector system.

(37) TOOLING: Featuring 17 throw-away insert styles, Kendex tooling is shown in form B-300 from *Kennametal Inc.* Inserts, made in square and triangular shapes, provide up to eight cutting edges per insert. Tooling eliminates grinding, cuts costs per cutting edges, and provides a chip control system.

(38) TROLLEYPHONE: The *Femco Inc.* communication system operates on FM carrier current and derives its energy from existing trolley wires or plant power lines. Microphone is said to be particularly suited to industrial applications where ambient noise is a factor or dust and moisture are prevalent.

(39) DUCTILE IRON: Up-to-date information on this cast iron that can be bent is given in a 28-page bulletin from *International Nickel Co.* Typical applications are: grate bars, crank cases, pipe, pumps, valves, and tractor hitches.

(40) V-BELT DRIVES: *Allis-Chalmers'* 74 page booklet 20P40 has multicolor tables for quick, easy selection of constant speed Texrope V-belt drives. Handbook also contains design features, basic drive principles, helpful operating hints, and data on sheaves.

(41) CONTROL TRANSFORMERS: *General Electric Co.* has a 32-page catalog GED-2767 covering a complete line of control transformers. A special section shows panel and machine tool voltage regulation curves for use in selecting the proper transformer for given applications.

(42) AUSTRALIAN PUMP: In production at *Carpco* is the Warman pump in the 1x¾-in. size, a small but rugged solids handling pump. These rubber lined pumps are fast becoming standard not only in Australia, where they were first developed, but also in the Far East.

(43) CINDERS & FLY ASH: Bulletin from *Fly Ash Arrestor Corp.* is illustrated with schematic drawings and photographs. Among other equipment, company manufactures multiple cyclone dust collectors, fly ash reinjection systems, smoke eliminators, and controlled ratio dampers.

(44) V-8 ENGINES: Le Roi Div., *Westinghouse Air Brake Co.*, has an 8-page bulletin on the 190-hp H540 and the 285-hp H844. Halftones, charts, drawings, and diagrams illustrate design, performance, and economy of these two industrial engines that operate on gasoline, natural gas, or LP gas.

(45) CONVEYOR BELT CARRIERS: *Stephens-Adamson Mfg. Co.* has a 15-page bulletin on conveyor belt carriers. Added to the S-A line is a long center roll carrier with 35° or 45° slope end rolls for greater carrying capacity on light materials.

(46) BAROMETRIC CONDENSERS: Form 9012-A describes *Ingersoll-Rand* barometric steam condensers. They are made in sizes to 120-in. diam and handle up to 12,000 gal of cooling water per min. The disc-flow type is suitable for any application, while the Ejector-Jet is used where the quantity of noncondensables is moderate and relatively clean cooling water is available.

(47) ALLOYS: *Coast Metals Inc.* has literature on hardsurfacing alloys. These materials consist of alloy-filled tubes, either in coils for automatic welding or cut to length for manual applications.

(48) EXCAVATING, LOADING: *Caterpillar Tractor Co.* has a brochure announcing production of the 933 and 955 Traxcavators. Oil-type clutch, modern hydraulic system, and convenient placement of controls are graphically detailed, as is the Traxcavators' ground level 40° bucket tip-back, which assures large loads at every pass.

(49) PLANT TELEPHONES: Brochure from *Automatic Electric Sales Corp.* shows the P-A-X business telephone system in use in a Detroit manufacturing firm. This plant-owned telephone system sharpens efficiency, conserves manpower, and assures contact between widely separated departments.

(50) MILL OPERATION: The September-October 1955 issue of "Deco Trefoil," published by *Denver Eqpt. Co.*, discusses operation of an up-to-date flotation plant on the Isle of Man. Plant is recovering lead-zinc from the tailings of an abandoned mine.

(51) ROPE SLINGS: Made by the Wickwire Spencer Steel Div., *Colorado Fuel & Iron Corp.*, Dura-grip rope slings have the advantage of a hand splice plus the safe handling of a smooth steel sleeve. Bulletin contains various assemblies for which slings can be used and a complete listing of dimensions and rated capacities.

(52) BATTERIES: Catalog from *Electric Storage Battery Co.* states that tubing and tube sealers encasing the active material and grid spines of the positive plates of Exide-Ironclad mine batteries are now made of polyethylene. This should increase battery life 20 pct.

(53) STORAGE SHELTER: Literature from *Yard-Stor Shelter Co.* shows portable sectional metal storage shelter that tilts, telescopes, and slides apart for easy access. Company now has a rental plant for emergency and temporary uses available through local crane and fork truck rental services.

(54) OXYGEN ANALYZER: Bulletin 108A from *Arnold O. Beckman Inc.* shows how the model F3 oxygen analyzer makes its measurement directly upon the oxygen content of the gas—not upon some remote secondary relationship. There are no filaments, catalysts, chemicals, or fuels to replenish and no orifices, valves, cams, or delicate mechanical parts to keep in repair or adjustment.

(55) ROOF-BOLTING DRILL: Bulletin C-50 from *Joy Mfg. Co.* is on the RBD-15 hydraulic rotary roof-bolting drill. This 15-hp unit drills wet or dry, tightens bolts, and has instant control without a gear shift. Motor provides thrusts to 5500 lb at 1050 psi; feed speeds to 60 fpm; rotation speeds to 650 rpm; and torques to 240 ft lb.

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New York, N. Y.

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MINING ENGINEERING

29 WEST 39th STREET

NEW YORK 18, N. Y.

How to pick the

RIGHT RIG *for your job*

Alberhill Coal and Clay Company selects its equipment carefully. The firm bought two Caterpillar DW21s after comparison demonstrations with other makes in their clay pit at Alberhill, Calif. Are they glad they chose Caterpillar? Listen to Harvey Gardner, superintendent:

"We've moved as much as 3480 bank yards in a nine-hour day with these two rigs, over a half-mile round-trip haul. The material was firebrick clay—so hard that it had to be ripped." The CAT* DW21s were push-loaded by a D8 Tractor.

This DW21's performance speaks for itself. However, you can count on even bigger loads in less loading time with the new DW21 (Series C) and the new No. 470 LOWBOWL Scraper. This rig incorporates time-tested Caterpillar features with advance design improvements, packs 300 HP at 1800 r.p.m. and has a capacity of 25 cu. yd. heaped, 18 cu. yd. struck.

As a result of comparing equipment carefully, Alberhill Coal and Clay Company is now standardized on Caterpillar. The firm owns five Caterpillar track-type Tractors, a Caterpillar Motor Grader and a D13000 Diesel Electric Set in addition to the two Cat DW21s. "We've had very little down time," Superintendent Gardner says, "and we get fast and efficient service from our Caterpillar Dealer."

Get all the facts. Your Caterpillar Dealer will gladly demonstrate—on your job—the tractor-scraper combination that will move the most material for *you* at lowest cost. Give him a call today.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Atomic Reactor Metals

AEC will invite proposals for supplying up to 100,000 lb of reactor-grade beryllium a year for the next five years. The Commission has been obtaining its beryllium from stocks at the Government-owned plant at Luckey, Ohio, which did not produce for AEC in 1955 . . . . Continental Uranium Inc. has signed a contract with AEC to build and operate a uranium processing mill at La Sal, Utah. The mill, designed to recover vanadium as well, is expected to be in operation by the summer of 1956, bringing to 14 the number of uranium mills operating in the western U. S.

Bituminous Coal Progress

With the 1955 bituminous coal output running some 20 pct above 1954's low and expected to reach 463 million tons, three responsible factors stand out: The steel industry, producing at a record level, is consuming more bituminous than ever before. Coal exports, largely for Western Europe, are almost double those of 1954. Finally there is the effect of the long-term increased dependence of utilities upon coal for the generation of electricity. Future prospects are for a maintenance of exports and an increase in coal consumption by the steel and electric power industries.

Canadian Mining Growth

Heavy sustained demand has raised Canadian mineral production above the previous record 1954 figure to an estimated $1.7 billion for 1955. The value of iron ore exports alone may exceed $90 million. Iron mines in the Quebec-Labrador area have shipped more than 7 million tons of ore this year, while Steep Rock has doubled shipments to 2¼ million tons. Uranium output is expected to reach $48 million following opening of two new mines in September.

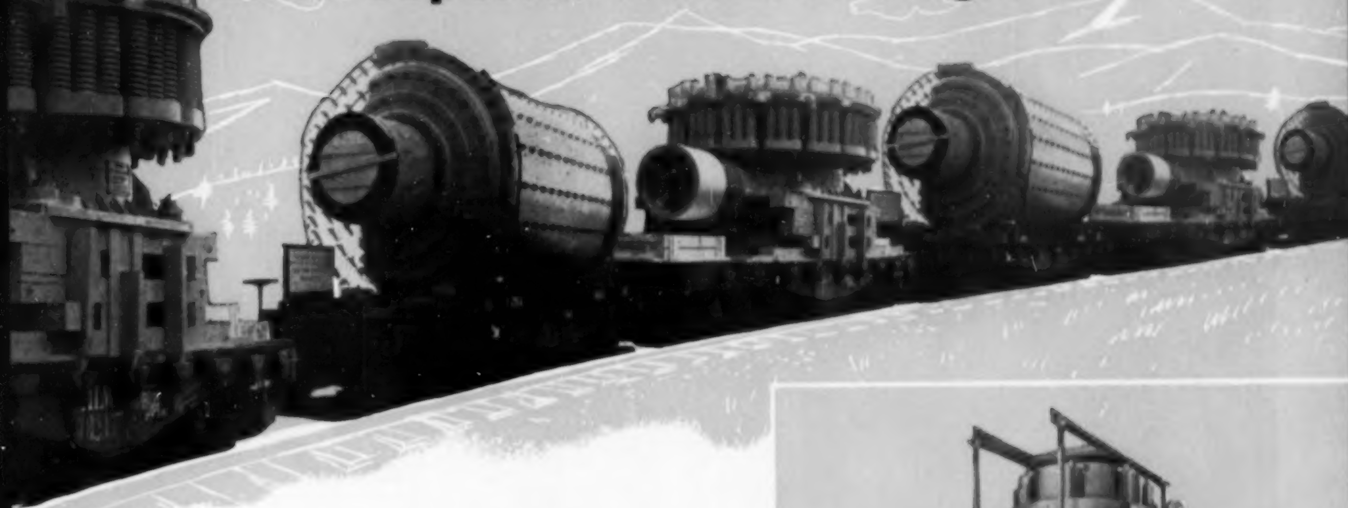
Western Mining

Kennecott Copper Corp. has announced the purchase from Combined Metal Reduction Co. of the lead-zinc property known as Butterfield mines near Lark, Utah . . . . A subsidiary of Standard Ore & Alloys Corp. has agreed to purchase the Penn mine in Calaveras County, Calif., which it expects to put into limited production within 90 days. The mine was first opened in 1861 and has produced zinc, copper, gold, and silver . . . . Idaho Maryland Mines Corp. is reportedly proceeding with plans for a new mill in Grass Valley, Calif., to process tungsten ore from its Brunswick and Union Hill mines.

Atlas to Raise Philippine Copper, Iron Output

The Orient's most important copper-producing installation is that of Atlas Consolidated Mining & Development Corp., Cebu, P. I., which began large-scale operation in February 1955. Some 5000 tpd of ore are being treated and plans call for doubling this tonnage by late 1956. Open pit mining is carried out in a disseminated chalcopyrite deposit averaging 1 pct Cu. Reserves are estimated to be in excess of 37 million tons. Atlas is also preparing the Mati iron ore properties at Davao on Mindanao Island for ore export to Japan. Shipments will start with 50,000 tons in the first quarter of 1956.

70 NORDBERG GRINDING MILLS and 37 SYMONS® CONE CRUSHERS for processing TACONITE in the Lake Superior Iron Ore Region...



SYMONS® CONE CRUSHERS and NORDBERG GRINDING MILLS have long proved their efficiency, dependability and economy in the profitable reduction of ores and minerals the world over. In the case of *TACONITE,* one of the hardest and toughest of all ores to process, the mining fraternity again depends on Symons Cone Crushers and Nordberg Grinding Mills for the economical production of large tonnages of fine crushed and milled product . . . as evidenced by the fact that, following extensive tests and research in pilot plants, 37 Symons Cones and 70 Nordberg Rod and Ball Mills were recently ordered for delivery to the mammoth reduction works now under construction in Northern Minnesota.

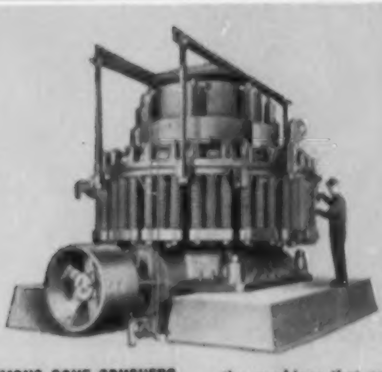
The thirty-seven Symons Cone Crushers . . . all Super Heavy 7-foot types, have been given the difficult assignment of secondary and tertiary crushing of the hard, tough Taconite Iron Ores. The seventy Nordberg Rod and Ball Mills were selected to meet the exacting requirements for primary and secondary grinding. Included are 33 rod mills—twenty-nine 10′ x 14′ units and four 10′ x 16′ units . . . as well as a total of thirty-seven 10′ x 14′ ball mills.

Thus, in Taconite operations . . . *as in all of the great ore and industrial mineral operations the world over . . .* NORDBERG MACHINERY is the outstanding preference among leading producers for processing great quantities of finely crushed and ground product at low cost.

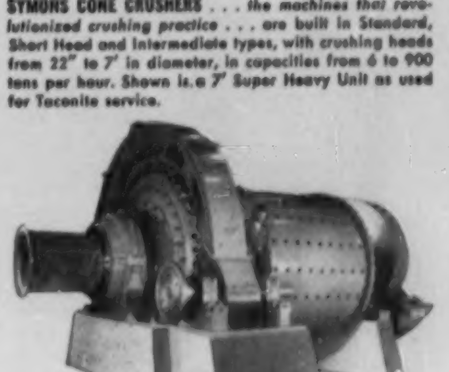
Write for further information on the machinery you need.

NORDBERG MFG. CO., Milwaukee, Wis.

SYMONS . . . A REGISTERED NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD



SYMONS CONE CRUSHERS . . . *the machines that revolutionized crushing practice* . . . are built in Standard, Short Head and Intermediate types, with crushing heads from 22″ to 7′ in diameter, in capacities from 6 to 900 tons per hour. Shown is a 7′ Super Heavy Unit as used for Taconite service.



NORDBERG GRINDING MILLS are built in ball, rod, tube, pebble and compartment types for practically all wet and dry grinding operations. Shown is one of the 10′ x 14′ Ball Mills for Taconite service.

M255

NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

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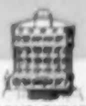
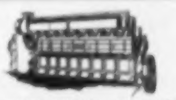


SYMONS GYRATORY CRUSHERS

NORDBERG KILNS and COOLERS

SYMONS VIBRATING GRIZZLIES and SCREENS

NORDBERG MINE HOISTS



NORDBERG DIESEL—DUAFUEL® and SPARK-IGNITION GAS ENGINES

Kennecott Sells Community Townsites in Four Western States to an Independent Realtor

Hopes to Encourage Home Ownership.

To make its housing units available for purchase on reasonable terms by its employes, Kennecott Copper Corp. has sold its community townsites in four states to an independent realtor. With the sale of these housing units and utilities, estimated at $5 million, Kennecott will discontinue its role of landlord and encourage home ownership among its employes.

New owner of the townsites in John W. Galbreath & Co. of Columbus, Ohio. This company has handled numerous housing projects of this type throughout the U. S. These include Dragerton and Columbia, Utah, for U. S. Steel Corp.; the community of Henderson, Nev.; 14 towns in the area of Uniontown, Pa., for Carnegie-Illinois Corp.; eight company towns near Birmingham for the Tennessee Coal, Iron & RR Co.; and Wilmerding, Pa., for Western Airbrake Co.

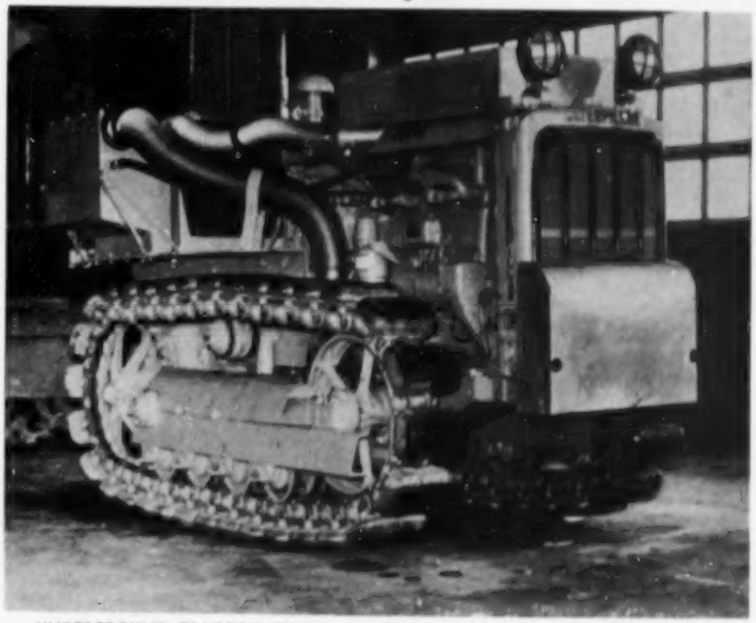
Kennecott's houses in Hurley, N. M., will be sold outright to Kennecott's employes by the Galbreath Co. Some of the houses in Santa Rita, near the Chino open pit copper mine, will be sold for eventual removal to new locations; others will be sold outright.

Sale of these houses is not expected to start until after the first of the year, as it will take some time to work out details. Kennecott officials have indicated that the Galbreath Co. will probably require six months to complete the entire program.

The Galbreath Co. will take over and operate utilities in Santa Rita and Hurley. Property now leased to churches and schools will be deeded by Kennecott to those institutions.

Other Kennecott communities affected are in Nevada, Utah, and Arizona. The transaction for the Nevada Mines Div. includes the towns of McGill, Ruth, and New Ruth and is estimated at $2 million. At the Utah Copper Div., homes in Copperton, Garfield, and the area adjacent to the Kennecott mills in Magna and Arthur will be affected. This transaction will amount to approximately $1 million. In Arizona the communities to be sold are Ray and Hayden, involving an estimated $500,000.

Air view shows New Ruth, Nev., one of the townsites involved in the sale by Kennecott. Other Nevada Mines Div. townsites involved are McGill and Ruth. Properties in Arizona, New Mexico, and Utah are also being sold.



UNDERGROUND TRACTOR: This Caterpillar D2 tractor has recently been approved for noncoal underground mines by the U. S. Bureau of Mines. Unit uses a National Mines Service Co. conditioner that lowers exhaust temperatures to 160° and removes some of the water soluble aldehydes.

"100% SATISFIED" with his GOLD MINE'S CAT* POWER

UP IN the hills north of Trona, Calif., near the legendary "lost" Peg Leg mine, are the gold mine and mill of Argus Development Company. Two Caterpillar Electric Sets and a Caterpillar Engine supply all power for them. According to Russell A. Donnelly, Argus' president, "We're 100% satisfied with these units. We like their easy starting in cold weather, and their economy, dependability and quick pickup in power."

A Caterpillar D13000 Electric Set furnishes power for crushers, conveyors and lights at the mill, which has a capacity of 100 tons of ore per eight-hour shift. Another Cat Electric Set powers the hoist at the mine. There is also a Caterpillar Engine, veteran of more than 7000 hours, in a Gardner-Denver compressor. Ore is trucked 8½ miles from the mine to the mill.

Excellent as these units are, the new Cat Electric Sets are even better. They are self-regulated sets, giving precise control of voltages from no-load to full load, and simplified operation without adjustments. The new Caterpillar Electric Sets produce greater power from more compact units . . . for easy installation or change of location. They are available in a complete range of sizes up to 300 KW for permanent installations or as portable power plants.

Find out for yourself why Russell Donnelly says, "We bought Caterpillar because it's tried and proven. We like the performance and the dealer service." Call your Caterpillar Dealer today for full information on the electric set that best suits your needs. And count on your dealer for fast, skilled service and parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR*

MODERN HEAVY-DUTY ELECTRIC SETS

J & L Steel Corp, Dedicates $1.5 Million Laboratory

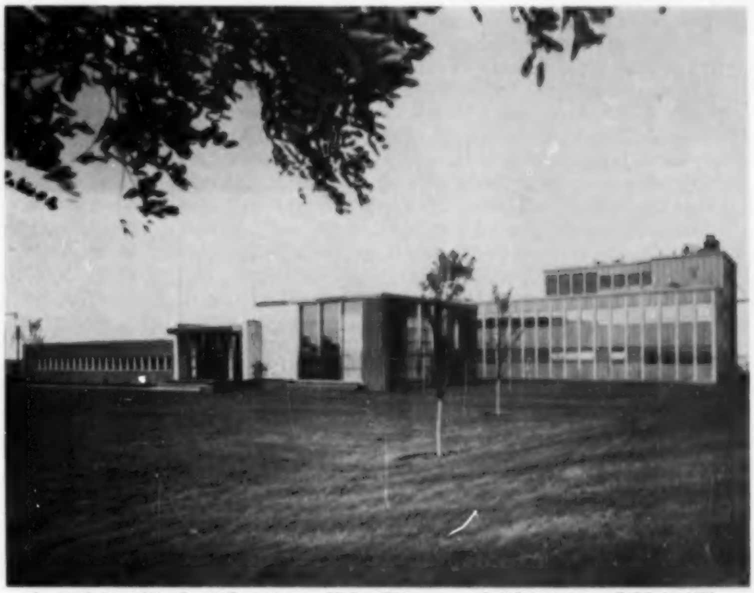
Jones & Laughlin Steel Corp. has named its new laboratory after Herbert W. Graham. Costing more than $1.5 million, this Pittsburgh building is said to contain the most modern equipment anywhere for handling the research problems of a steel company.

Investigation is served by the latest equipment for physical testing, metallographic studies, X-ray diffraction, spectrographic analysis, and analytical chemistry. Research programs will cover all phases of J&L's operations: raw materials processing, iron and steelmaking, production of finished steel products, organic chemistry processing, and development of new instruments for automation and quality control.

The laboratory also houses the administrative activities of the Research Div., a 3500-volume library, offices, and a fully equipped machine shop.

Total Research Div. staff numbers 127, some of whom remain at the laboratories adjacent to the company's Pittsburgh Works. Others operate the ore research laboratory at Negaunee, Mich.

The new laboratory has about 40,000 sq ft of floor area. Movable metal partitions have been provided for subdividing various areas, and all utilities are run in racks inside the partitions. Repairs or additions can be carried out by simply removing face panels from the partitions.

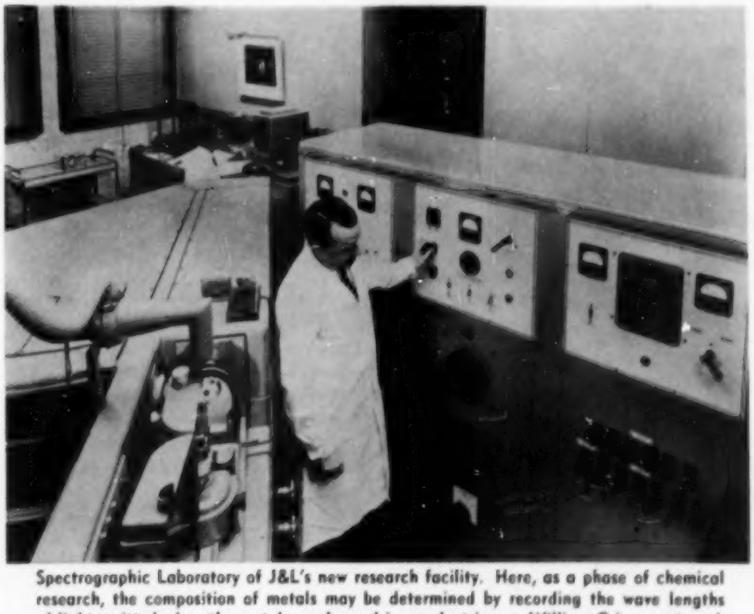


Jones & Laughlin Steel Corp.'s new $1.5 million research laboratory on Baldwin Hill, South Side, Pittsburgh. Designed by Prack & Prack, architects, the laboratory was built by Ragnar Benson Inc., and has a floor area of about 40,000 sq ft.

Named After a Research Pioneer

Herbert W. Graham, after whom the research facility is named, has served J&L for more than 40 years. Mr. Graham, AIME Howe Lecturer in 1947, graduated from Lehigh University in 1914 and started with the company the same year. He became chief inspector of the Pittsburgh Works in 1923, chief metallurgist in 1927, general metallurgist in 1928, and was elected vice president-technology in 1947. Mr. Graham became vice president-research in 1953 and on October 15, 1954 was appointed consultant to the president.

H. W. GRAHAM



Spectrographic Laboratory of J&L's new research facility. Here, as a phase of chemical research, the composition of metals may be determined by recording the wave lengths of light emitted when the metals are burned in an electric arc. William Grimes, research chemist, is shown operating the two-meter grading spectrograph, a product of Applied Research Laboratories.

Part of Expansion Program

The laboratory itself is termed "the most recent step in J&L's continuing post-war expansion and improvement program." Projects completed have involved $500 million and further projects for the 1955 to 1958 period will increase expenditures by $250 million.

IN years to come when mining engineers are asked how they happened to choose mining, many of them may say, "In high school I read a book about a kid who went mining with his uncle."

An AIME member, who has traveled thousands of miles in Cyprus, Portugal, Ethiopia, Saudi Arabia, Yemen, Iran, and British and French Guiana, has written a new book. He is already the author of two books on Saudi Arabia, but this is a novel and it is directed to a younger audience.

It is *Keith Arnold in Mining Engineering** by Karl S. Twitchell with Robert Wyndham. Mr. Twitchell, a graduate of Kingston School of Mining of Queens University in Ontario, first started as an assayer-helper in the DeLamar mine in Idaho. Later he helped organize the Saudi Arabian Mining Syndicate and the Arabian American Oil Co. His story is set in Ethiopia and Arabia. Unobtrusive details on mining are mingled with descriptions of Ethiopian and Arabian customs. The hard work, dust, sand, and grind are never minimized, but the adventure and excitement are there too. Better start thinking up reasons to tell your young son or nephew why you haven't seen any gazelle fights. They make bull fights sound tame.

OUR 13th floor neighbor, Ralph H. Phelps, director of the Engineering Societies Library, recently sent down an editorial from *Science*. It first appeared in *Nature* in London. With this well traveled piece, Mr. Phelps wrote, "As a librarian flooded with publications—some worthwhile and many not worthwhile—I was much intrigued. . ."

Rushing into Print

There is a tendency these days among scientists to rush into print. More often now than ever before some scientists, having submitted a communication for publication, eventually ask to withdraw it or to be allowed to modify it because they either have discovered an error or have since learned that some of the work has been done elsewhere. This tendency is also revealed in the appalling state of corrected proofs received from some authors—sometimes peppered with corrections and changes which are, at the least, very expensive to make. Rushing into print is also inspired by the bugbear of priority. For example, the request by an author that his communication should be treated as urgent because he has learned that similar work is being done elsewhere is now treated like the cry of "Wolf! Wolf!" Requests of this sort are happening far too often. How refreshing it is when one team of workers, having heard that another is working along the same lines, gets in touch with the second group and arranges a joint communication.

There is much complaint today concerning the amount of scientific literature that each scientist must read if he is to keep pace with his own subject. There are many reasons for this overwhelming spate, not the least of which is the overenthusiasm of scientists themselves. Too many of them imagine that just because they have written a scientific paper it is worthy of publication. The result is that the whole field of our literature extends over a wide range of scientific merit.

Much of the detail published in a research paper is of limited interest and value. Men of science might well consider publishing only the main points of their research and filing the rest for possible reference. It was the late Lord Rutherford who once said that when writing a letter to *Nature* if you cannot say all that is really necessary in 500 words or less, then something is wrong. If every scientist throughout the world believed this and took it to heart, then I can visualize even *Nature* having no time-lag in publication at all. It is significant that, though *Nature* frequently returns a communication to an author with a request that it be reduced to two thirds or one half of its present length, I can recall only two or three instances in the whole of my more than a quarter of a century connection with *Nature* of an author replying that he could not cut his communication.

I rather imagine it would be a good idea if every communication submitted were returned without even being read by the editor, with a covering note asking: (i) Are you sure you have said what you want to say? (ii) Have you said it in the minimum number of words? (iii) Is it worth saying at all? Too many scientists, especially younger ones, seem to assume that the value of a scientific paper varies directly as its length. I would strongly urge that men of science thoroughly train themselves to hold their lips tight and their pens dry until they know the facts or are sure of what they wish to say.—L. J. F. Brimble, *Nature* (London).

OF the Seven Wonders of the Ancient World, only the Egyptian Pyramids are left. No traces of the Hanging Gardens of Babylon remain. Phidias' Statue of Zeus was destroyed by war. The Temple at Ephesus couldn't stand up to Nero and Alaric the Goth. The Colossus of Rhodes, the Pharos Lighthouse at Alexandria, and the Tomb of Mausolus were wrecked by earthquakes and cut up for junk. There are surviving fragments of the Tomb of Mausolus in the British Museum, but tourists do not have their pictures taken on them.

Seven Modern Civil Engineering Wonders of the U. S. have been selected by the American Society of Civil Engineers. Don't quarrel with the first; the order is alphabetical.

Chicago Sewage Disposal System. This makes Hercules look like a mere handy man, for it meant reversing the flow of the Chicago River and the construction of the world's largest treatment works.

Colorado River Aqueduct. Ira Wolfert in *Reader's Digest* wrote that it looks "as though it had been dropped from the moon." It now serves 66 municipalities in five counties that have a total population of 6 million.

Empire State Building. Statistics here would almost fill one of its 102 stories. It has "700 million lb of steel, stone, wood, brick, aluminum, and other materials." Other *materials?* Does this include secretaries, boys delivering coffee, sightseers? However, the building's weight is 365,000 tons less than the excavated rock and dirt. This is somehow a bit

* Dodd, Mead & Co., $3.75, 183 pp. 1955.

comforting, though we don't know why.

Grand Coulee Dam and the Columbia River Basin Project. This involved placing the largest single mass of concrete in the world, more than 10 million cu yd.

Hoover Dam. World's highest dam, 726 ft. That is about half the height of the Empire State Building.

Panama Canal. Called by James Kip Finch "the greatest of geographical surgical operation."

San Francisco-Oakland Bay Bridge. Total length of steel over water is about 6 miles. The tunnel bored through Yerba Buena Island is the largest, though not the longest, tunnel in the world.

Only one of the Seven Wonders selected by ASCE was built by private enterprise—the Empire State Building. All the Ancient Wonders must have been Government jobs.

▲

AS everyone knows, some of the greatest fortunes during the California Gold Rush were not made by miners. In San Francisco in 1849 and 1850 shirts sold for $82 apiece, mules for $360, and watermelons for $20.

A year ago last month four Grand Junction engineers, Donald A. Miller, James R. Wilson, G. Herb Gill, and Robert Van Houten took a few days off from their jobs building precision instruments to take a prospecting trip in Utah. In camp one night they got talking about Geiger counters and other tools of the Atomic Age sourdough. Ideal equipment was unavailable. Why didn't they make it?

They never went back to their old jobs. They sent in their resignations, pooled their savings of $2500, and formed the Atomic Engineering Corp.

An abandoned slaughterhouse in Grand Junction became their factory. Their first product was a gamma logging probe, said to have been instrumental in the Sabre Uranium strike at Grants, N. M. Then followed Geiger counters, lightweight portable logging reels, and drilling rigs. But unlike the early San Francisco merchants the new company kept its prices down. The Holey Cat is claimed to sell for one quarter to one tenth the cost of other rigs.

Today the company, an independent subsidiary of Colonial Nuclear Industries Inc., expects its first 12 months' sales to top $250,000. It has $25,000 worth of precision tools and equipment, 16 employes, and a brand-new 4200-sq ft plant. And it's staying in Grand Junction.

▲

SOMEWHERE among your college notebooks you may have jotted down that professor's remark about all the things that could be made with absolutely pure iron, if it could be produced. In March 1954 the General Electric Research Laboratory made your notebook obsolete when it announced that perfect crystals of iron had been achieved. These have tensile strengths of approximately 1 million psi.

Since then GE scientists have been busy with other metals. Perfect crystals of gold, silver, platinum, copper, nickel, and cobalt have been grown. Research has shown that perfect copper crystals can withstand tensile stress as high as 600,000 psi. In contrast, samples of ordinary annealed copper, composed of more than one crystal, break at 30,000 psi, and single imperfect crystals break at only 5000 psi.

Strength tests of ordinary metals are usually conducted on specimens of ¼ to ½-in. diam. It was, however, difficult to test perfect crystals, because the so-called crystal *whiskers* are only about a thousandth of an inch thick. The paper on which this is printed averages 0.003125 in. thick.

In the new tensile strength test devised by GE scientists the whisker is placed in a vertical position with the upper end embedded in a glass-like substance. The bottom of the whisker is similarly attached to a glass cylinder floating in a container of oil. The oil is siphoned out of the container, thereby reducing the buoyant force supporting the glass float and causing its weight to apply a downward pull on the whisker. The resulting elongation and eventual breaking of the whisker are projected on a screen for viewing.

The old method measured the amount a whisker bent under a load applied from one side. With this method the greatest stress was concentrated at one point, rather than being evenly distributed through the test sample. Both systems of testing are in close agreement and both will be used at GE in the future.

Besides their great strength, crystal whiskers remember their original shape. When stressed beyond a certain point a whisker will remain bent, but if it is heated it will return to shape. A deformed whisker of copper, for example, when heated 40 min to more than 1000°C, shows this remarkable recovery. It is as though a crumpled automobile fender were to spring back into shape after merely being heated.

▲

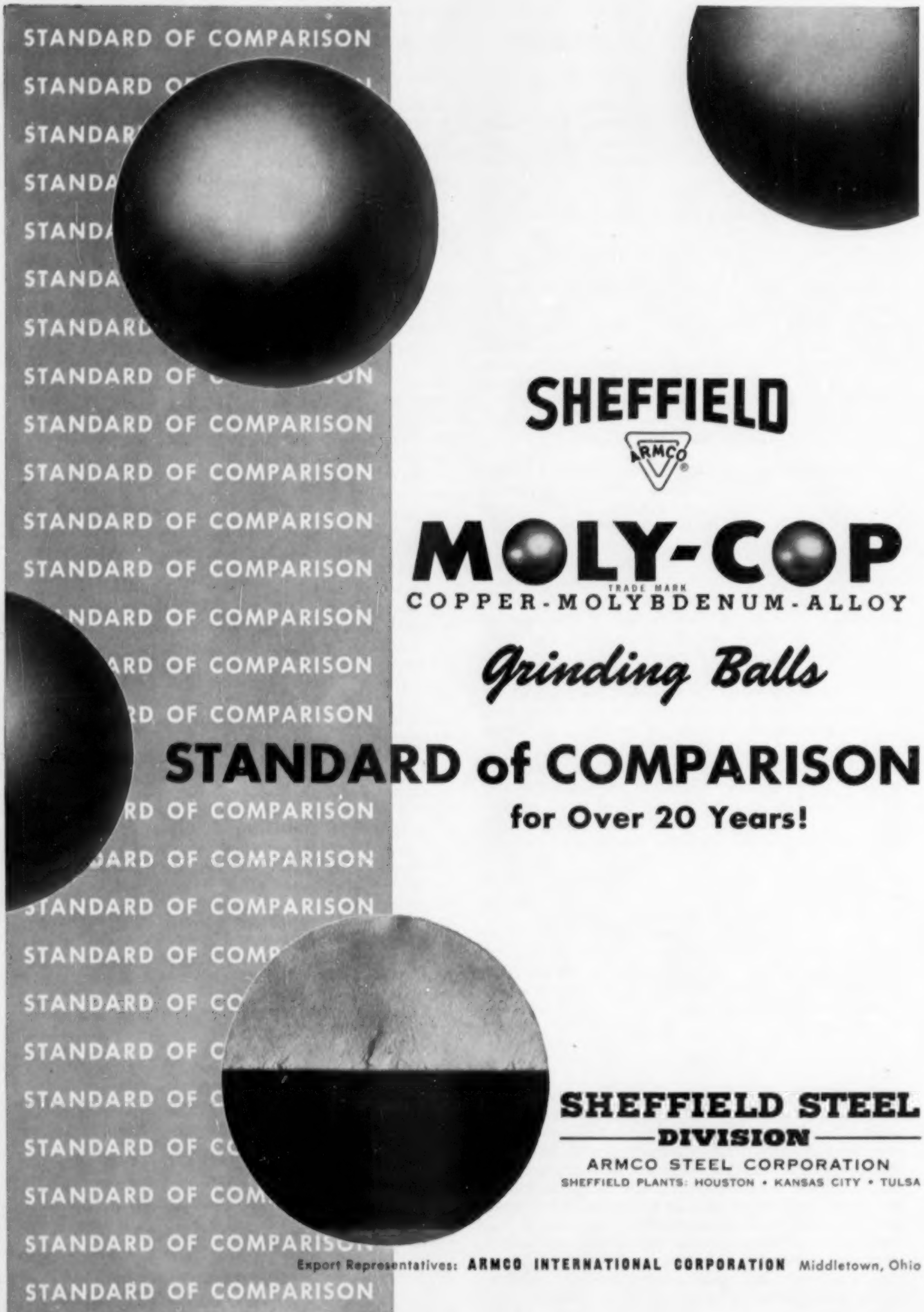
JOHN P. Frey, former president of the Metal Trades Dept., American Federation of Labor, began his career as a molder apprentice in 1867. Working 10 to 12 hr a day, six days a week, during his first year of training he received 75¢ a day. In his second year his wage was increased 25¢ a day. He was doing almost the same work as helpers who received $1.50 a day.

This is a fairly recent example of apprenticeship. Others in Colonial days, including Benjamin Franklin and Paul Revere, are described in the 1955 edition of *Apprenticeship Past and Present*, issued by the U. S. Dept. of Labor.*

Early apprentice indentures are given for 1640, 1676, and 1715. These are contrasted with apprentice training procedures of the present day.

An indenture for 1676 reads: "Fornication he shall not commit, nor contract matrimony within the said time. The goods of his said master, he shall not spend or lend. He shall not play cards, or dice, or any other unlawful game, whereby his said master may have damage in his own goods, or others, taverns, he shall not haunt, nor from his master's business absent himself by day or by night . . . ." Don't feel too sorry for this poor fellow; his indenture was only for 12 years and 5 months.

* Superintendent of Documents, *Government Printing Office*, Washington 25, D. C. 20¢.



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AIME SHOWS RECORD GROWTH

Editorial Director Rix Beals walked into the Secretary's office last month with an opportunity for me to write *Drift* for January. This is a particularly opportune month, since it offers a chance to review the activities of 1955, a year that included the last several weeks of Leo Reinartz' term of office and most of H. DeWitt Smith's year as President. During 1955 the Institute had the largest net increase in new members, including Student Associates, of any year in its history. Total membership at the end of the year was approximately 26,300 and AIME now has 69 Local Sections and 71 Student Chapters.

Two or three-day regional meetings are being encouraged to bring to more members the technical papers that time does not permit at an evening Local Section meeting and that distance prevents many members from hearing at national gatherings. However, Annual Meeting attendance has not suffered.

Chicago Annual Meeting

The 1955 Annual Meeting was the largest out-of-New York meeting on record. Perhaps the readers will understand that the writer remembers this meeting as the occasion when he was elected Secretary of the Institute as well as for the unusually fine meeting arranged by the Chicago Section under the general chairmanship of Bud White. Just nine years before, the Annual Meeting in Chicago had been the first Institute meeting attended by your Secretary as a staff member.

During the year records were broken by many other meetings of Institute groups, of which we

MINING engineering DRIFT

were fortunate enough to attend the Petroleum Branch Fall Meeting in New Orleans with over 2500 registered; the Institute of Metals Div. Fall Meeting in Philadelphia attended by 830; the Electric Furnace Steel Committee Meeting in Pittsburgh, which attracted 950; the Rocky Mountain Minerals Conference and MBD Fall Meeting in Salt Lake City with about 450; and the all-day, all-AIME Pittsburgh Section meeting, which drew over 800. Needless to say, outstanding technical programs at these meetings played an important part in setting these attendance records.

European Meeting

Particularly gratifying was the opportunity to attend the Joint Metallurgical Societies Meeting in Europe last June. Former AIME President Clyde Williams and your Secretary represented the Institute at this international gathering participated in by eight societies from Europe and the U. S. and attended by well over 1000 registrants.

The year 1955 will also be remembered for the letter ballot, which by a 12 to 1 majority authorizes the change in the Institute's name next month to American Institute of Mining, Metallurgical, and Petroleum Engineers, recognizing in the name a growing group of the Institute representing nearly a third of the membership.

Balanced Budgets

The year 1955 was also the first year in which each of the three Branches balanced their respective budgets. Although this is difficult for the Metals Branch to do without curtailing its extensive publications program, a balanced budget was accomplished through support of publications by industry. The basic metallurgical information being presented does not lend itself to support by advertising, and certainly the cost of its publication cannot continue to be borne in its entirety by professional men, individually, through dues. Industry has, however, recognized that it as well as the membership stands to profit greatly by the recording of basic information that has been obtained at a cost many times that of the cost of publishing.

THE Institute carries out its objectives primarily by holding meetings and publishing papers. There are many other services your professional society performs, both tangible and intangible, for members and for society as a whole. Some of these are little known to the membership and it is proposed to devote some space in this column during the year to keep you informed of these activities.

Role of ECPD

The Engineers' Council for Professional Development is responsible for the accrediting of engineering curricula at the colleges in this country. The ECPD is active on an all-engineering basis in bringing to the attention of qualified high school students the possibilities of engineering as a career and has a program of professional development for recent engineering graduates.

The Engineering Societies Library is one for which the engineering profession, the largest profession for men in this country, can be proud. It is partially self-supporting. A large part of the balance of the cost to AIME is paid by an endowment fund for this purpose.

The Engineers' Joint Council sponsored the Nuclear Engineering and Science Congress in Cleveland in December. The Engineering Manpower Commission, a division of EJC, is independently financed by industry. However, its policies are established by the EJC Board. EMC has improved the effective use of engineers in this country particularly with regard to the military services and deferments for civilian needs.

These services, representing joint efforts by the five principal Engineering Societies, are partially self-supporting. Frequently the AIME portion of the balance of the expense is borne by income from endowment funds for such purposes. Occasionally staff members serve on such committees or take time to obtain information for these groups. But the greatest part of such services is made possible by the extensive voluntary work of AIME members serving on committees.

A Happy and Prosperous New Year to you all.

Ernest Kirkendall

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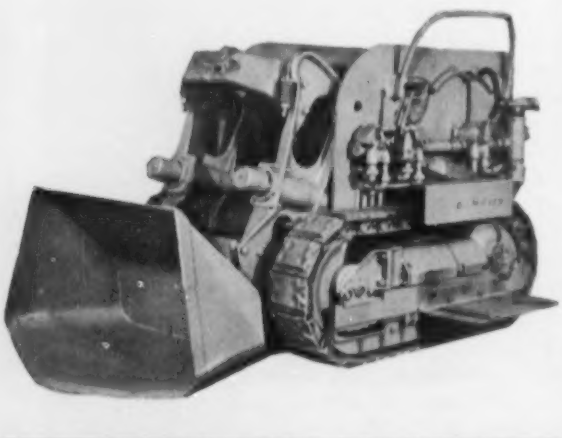

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LEADERSHIP IN ACTION

Jackleg Drilling in the Tri-State District: Longhole Prospecting and Production

by S. S. Clarke and Douglas C. Brockie

LONGHOLE underground drilling has been carried on in the Tri-State area at various times over the past 35 years or more. W. F. Netzeband reported on this topic in 1926[1] and in 1930.[2] More recently it has been found that in certain areas of the Picher field, Oklahoma, and under certain conditions, the jackleg or jumbo-mounted drifters can be used more economically and to greater advantage than surface churn drillholes for prospecting.

To understand better the problems involved in Eagle-Picher's longhole prospecting program it would be helpful to cover the geologic criteria affecting it. Much has been written about the geology of the Picher field. A more complete description than that given here can be found in a recent paper by J. P. Lyden.[3]

How Geology Affects Prospecting Program

Generally speaking the surface of the western two thirds of the Picher field is underlain by the Cherokee shale formation of Pennsylvanian age. Due to the regional dip of the beds to the west this formation varies in thickness from zero in the southeast to around 200 ft on the western edge of the field and no ore deposits occur in the formation. Below the Cherokee lie the Chester, Warsaw, and Keokuk formations, all Mississippian in age, the most important ore horizons being found in the Warsaw and the Keokuk. G. M. Fowler and J. P. Lyden subdivided these formations on the basis of lithologic differences. The Warsaw was differentiated into C to J beds, and the Keokuk into K to Q beds. Some ore is found at the base of the Cherokee but is mined only rarely due to the hazardous mining conditions encountered because the incompetent Cherokee shale forms the back. In certain areas of the field D bed has produced small amounts of ore.

The closest ore horizon of importance to the surface is E bed. Below E bed are the important ore horizons of GH, K, and M beds separated by the usually barren F and L beds. The interval from the base of the shale to E bed varies, as erosion has cut out all or part of the Chester formation. Ordinarily this interval ranges from 50 to 100 ft. This means that a surface churn drillhole has from 100 to 250 ft of essentially barren rock to penetrate before reaching the 60 to 70-ft section where the E, GH, and K bed ore may be intersected.

Deformation of the sedimentary beds resulted in folding, shearing, and fracturing along which subsequent mineral solutions migrated both horizontally and vertically. The ore and gangue mineralization is found to be related to these shearing trends. For purposes of this discussion the mineralization can be divided into two types, dolomite and jasperoid. The jasperoid areas consist of chert, jasperoid, and calcite and the ore minerals sphalerite and galena. This area usually has considerable open space such as caves and apertures between large boulders. In the dolomitic areas, the same minerals and rocks are present in addition to gray and pink dolomite, but there is usually very little calcite present, and although there is still open space, the openings are not so large nor so numerous. The broken brecciated nature of the ground is more noticeable in M bed and to a lesser degree in the upper beds. The above remarks apply to the ore horizons such as E, GH, K, and M beds. The massive chert horizons, D, F, and L beds in the mineralized areas, are usually strongly fractured and broken, the ore at times depositing in these fractures and crevices.

In many areas the mineralization in one bed has a vertical relationship to that in the beds above and/or below, which makes it ideal for a longhole prospecting project. Most of the holes are drilled at angles from 45° to 90° both up and down, the up holes being the more numerous to date. A few horizontal holes have been tried. A big problem has been in the recovery of cuttings from the down and horizontal holes. As described above, most of the areas where drilling is contemplated have considerable open space. As long as the down or horizontal hole remains in solid ground cuttings are obtained, but when the return water is lost in the openings or loose ground, the cuttings are lost or the bit and steel wedges. Diamond drilling has been tried in the past but has not been satisfactory because the highly abrasive nature of the rock resulted in high diamond cost. Due to the size and number of the openings, cementing does not seem to be an economic solution.

Longhole Prospecting Equipment

In those areas that have been extensively mined in either the upper beds or M bed the jackleg or standard drifter has recently played an important part in finding orebodies that have been overlooked in the past. Holes are spotted from information obtained by detailed geological observation.

The jackleg is used wherever the back is not too high. Holes have been drilled into the back from setups on the floor, from the platform on an old battery truck, and from the top of the muck in spare loaded ore trucks. Where the back is beyond the reach of such setups standard drifters on production jumbos are used. Production jumbos, depending on size, can reach 20, 40, and 65-ft backs. There is no restriction in the use of jacklegs for down or horizontal holes with the exception of the availability of air and water. Use of production jumbos is restricted to areas where roads have been constructed.

S. S. CLARKE is General Mine Superintendent, and DOUGLAS C. BROCKIE is Senior Geologist, Tri-State Mines Unit, Mining & Smelting Div., The Eagle-Picher Co., Cardin, Okla.

To date, most of the longhole work has been concentrated in the Big Chief, Blue Goose No. 1, and Bilharz mine units.

At the Big Chief unit most of the longholes have been drilled with an Atlas Copco RH-754 jackleg (3200 blows per min) and Atlas Copco equipment as follows: 1 9/16-in. (40 mm) tungsten carbide insert chisel-type bit with ⅞-in. hex steel and rope threaded type of couplings. Thor, Joy, and Ingersoll-Rand jacklegs were also tried.

No jackleg work has been done at the other two units as the backs were too high. At the Blue Goose No. 1 unit longhole work has been about equally divided between 20 and 40-ft jumbos using Ingersoll-Rand DA-30, 35, and 505 drifters. I-R Carset 2-in. bits with ⅞-in. hex steel and couplings of the Timken threaded type were used. The longest up hole to date, 93 ft long at a +80° angle, was drilled at this unit from the basket of a 40-ft jumbo. The drillers experienced no great difficulty from the weight of the steel involved.

At the Bilharz unit all the longholes have been drilled with production jumbos and equipment except for water swivels and I-R type 2-threaded couplings. I-R 2⅜-in. Carset bits and 1¼-in. round steel were used.

Results and Costs

At the Blue Goose No. 1 unit all holes except two have been up holes, as the main mine level is in M bed and the search was for possible hidden orebodies above the mineralized lower level runs. The two exceptions were 30 and 60-ft horizontal holes, from which a good cuttings recovery was obtained.

Forty-seven holes have been drilled at this unit, totaling 1920 ft for an average of 41 ft per hole. Nine distinct areas were drilled (average five holes per area), five of which indicated ore. Of the five areas, two have been partially mined and the ore found substantiated the drilling results.

No accurate costs were kept, as this drilling was done in conjunction with production work. The first holes were estimated to cost $2.00 per ft, with an average for the 1920 ft of $1.50 per ft. This cost includes lost holes, their footage (five holes, 128 ft) not being included in the 1920 ft. Some of the later drilling under ideal circumstances averaged $1.37 per ft. Much of the early work was done on an experimental basis, which accounts for high costs.

Only a few down holes have been drilled at the Big Chief unit, most of the up holes prospecting for E bed from the GH level. Altogether, 158 holes have been drilled, totaling 4782 ft for an average of 30 ft per hole. Twenty areas were drilled (average eight holes per area), 11 of which indicated ore to have been found. Four of these areas have been tested by raises and the drilling results have been substantiated. The down hole cuttings recovery was poor and unrepresentative as to grade, but enough was recovered to show the type of mineralization.

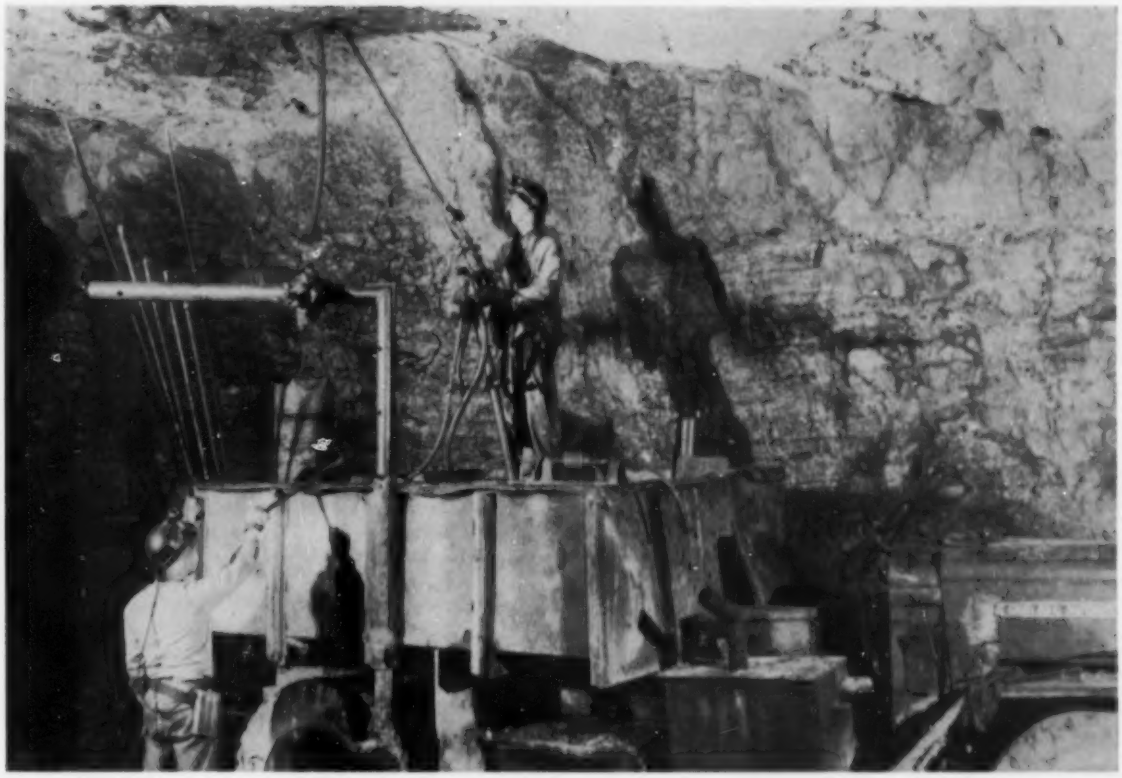
Accurate cost figures are available at this unit, as this work was done by a single development crew.

Drilling Performance

	Mine No. 1	Mine No. 2		Mine No. 3	Mine No. 4	Totals and Averages	Comparison with Drifters 1¼-in. Steel 2⅜-in. Bits
Drill shifts	288	178	315	113	264	1,158	14,282
Tons broken	12,215	5,565	14,748	6,606	10,047	49,181	1,208,885
Holes drilled	1,971	1,425	2,362	696	1,980	8,434	94,529
Footage drilled	17,123	8,218	18,058	6,513	19,065	68,977	980,931
Bits purchased	—	—	36	15	40	91	2,096
Comb. bit and steel purchased	67	38	—	—	—	105	—
Steel breakage	14	21	31	35	24	125	4,206
Feet drilled per break	1,223	391	582	186	794	551	233
Tons broken per drill shift	42.4	31.2	46.8	58.4	38.0	42.5	84.6
Holes drilled per drill shift	6.8	8.0	7.5	6.1	7.5	7.2	6.6
Feet drilled per drill shift	59.4	46.1	57.3	57.6	72.2	59.5	68.7
Bit cost per ton, $	0.122*	0.130*	0.035	0.033	0.067	0.066	0.038
Bit cost per ft	0.087*	0.087*	0.029	0.034	0.035	0.047	0.047
Tons broken per ft drilled	0.71	0.67	0.82	1.01	0.53	0.71	1.23

*Carbide insert in drill steel

Owing to the smaller diameter of some blastholes, it is necessary, in some setups, to drill two or three more holes per round in order to get good breakage.

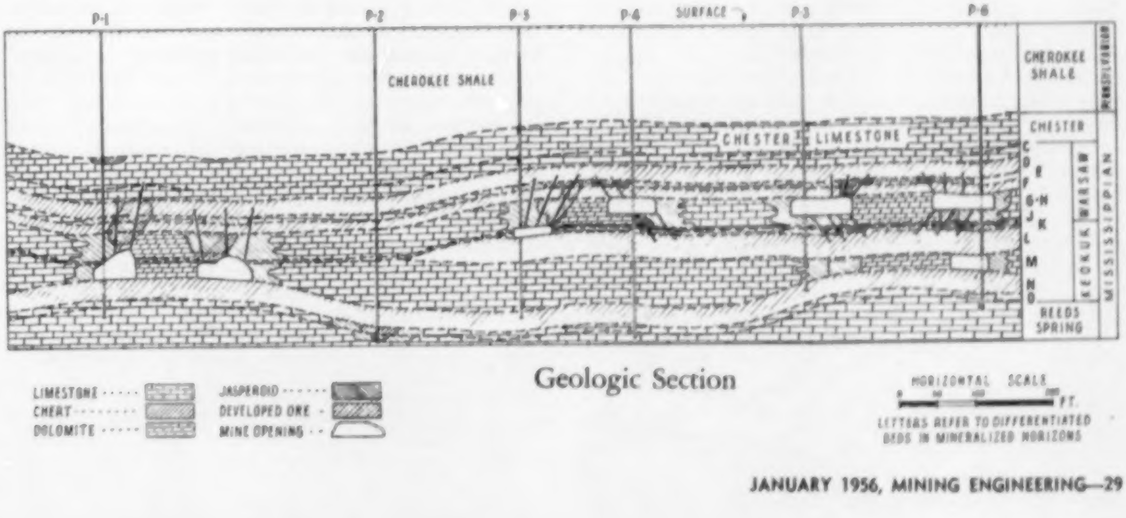


Cost of labor was $5297.20 and cost of repairs and supplies $2152.80, making a total of $7450.00 for the drilling of 4782 ft, or $1.56 per ft. Lost footage (19 holes, 365 ft) if included in the above total would reduce the cost to $1.45 per ft. Fifty-eight bits were used to drill the 5147 (4782 + 365) ft; 11 bits were lost due to breakage of steel, with an estimated half drilling life left. This would average out at 89 ft per bit. Seventy-five feet of steel was lost due to steel breakages.

Of 54 holes drilled at the Bilharz unit, 14 were down holes from which the cuttings recovery was only fair. Most of the drilling at this unit was done by either production or development crews, so that it was difficult to separate costs. The drilling was restricted to prospecting for E and K beds from the GH level. This means that the holes were short, the 54 holes drilled totaling 1222 ft for an average of 23 ft. Under ideal conditions, 235 ft were drilled at an estimated cost of $1.14 per ft, including labor, repairs, and supplies. It is estimated that normal costs will be similar to the Big Chief and Blue Goose No. 1 units.

Of seven areas drilled, six indicated the presence of ore and two of these have been tested by raises with favorable results.

At another mine unit some horizontal holes indicated ore to be present 45 ft out in the wall. The holes were inclined up 10° so that they would cut across the flat-lying beds and avoid unrepresentative cuttings. Upon drifting out to the supposed ore it was found that the holes had followed rich bands and the ore was too low-grade to mine. In the future, holes of this type will be drilled at a steeper angle.



Geologic Section

Some experimental down hole work was done at the beginning of this program. Using an Atlas Copco jackleg and ordinary mine air and water pressures it was possible to drill holes 40 to 45 ft deep at −60° and still recover sufficient cuttings by return water to identify the rock type. The trouble again was the loss of return water in openings and caves, and the wedging of the bits in soft spots and openings.

At the Blue Goose No. 1 unit it was found that the steel was breaking in the threaded section within the couplings when the 2⅜-in. bits were used on ⅞-in. steel in the longholes. Apparently the large diameter hole allowed too much vibration, especially in ground that had a tendency to ravel. A switch was made to 2-in. bits and the breakages were lessened considerably.

R. L. Haffner experimented with the use of Aquagel and waterproof cement mixtures for plugging loose and open ground on down holes. It was found that a mixture of three parts of Aqua-gel to one part of cement plastic worked moderately well with loose ground or openings up to 24-in. size. Return water was obtained and it was possible to deepen the hole.

Ore was encountered in 22 of the 36 areas drilled in the three mine units. To date, eight of these areas have been opened up or partially mined and the presence of ore has been confirmed. The grade has not checked out the drilling in every case, but what has been opened up is at least break-even grade. This is true, of course, in the case of surface churn drillholes as well, in that the indicated grade differs from the actual mined grade. Many of the holes, although not containing ore, did yield information upon which subsequent holes were spotted. In other cases, holes have shown that further drilling in an area is unwarranted.

At the present time the approximate cost of longhole drilling is about $1.50 per ft as compared to a contracted surface churn drillhole cost of $1.95 per ft (6¼-in. hole). The big advantage, in addition to the cost differential, is that all the longhole drilling is in the productive zone of mineralization, whereas the surface churn drillhole has the unproductive zone to drill through as well. This means that from five to eight 40 to 50-ft longholes can be drilled in the productive area for the cost of one churn drillhole, depending on the area.

Experiments are now under way with dry drilling and dust collectors on down holes, but to date work has not been sufficient to justify any conclusions.

Jacklegs Play a Role in Production Applications

THE final cleanup of small spots of ore in the walls and roof of some of the worked-out areas led to consideration of adapting jacklegs for this work, as in many instances the areas did not appear to contain sufficient tonnage to warrant moving in a large jumbo.

The ease with which the jackleg could be quickly moved from one spot to another and the fact that one miner could handle it led to its adoption as a *tramp* drill until it was determined if the orebody could yield a large tonnage. The units proved their worth in cutting raises and opening up the orebody to determine whether the orebody was large enough to warrant the installation of a jumbo or to continue mining with jacklegs.

Work is still in the experimental stage and drills, bits, and drill steel have not been standardized. Ingersoll-Rand, Thor, Copco, and Joy jacklegs are being tested. The drill steel being tried is ⅞-in. hex, Crucible 4-E, Bethlehem chrome moly and Copco Swedish make. Some 1¾-in. tungsten carbide bits made by Copco, Timken, and Ingersoll-Rand are being used. Some Copco steel that had the carbide insert in the steel, thus making a bull or chisel bit, was used on jackhammers for boulder breaking and some 12-ft lengths for jumbo drilling. Where the formation was of uniform nature these bits were quite successful, but in bouldery ground or ground that tended to ravel they were not satisfactory, as they mucked easily.

In the operation of jacklegs, it was found that a young miner with little previous drilling experience, but trained by a factory representative, made a much better operator than an old-timer who could not, or would not, flex to the drill, but fought it nearly all the time and finally gave it up as too hard.

It is not the authors' opinion that the *leg* will entirely supersede the hammer drill in this district. It has its place in the production operation. As benefits are realized and operating techniques improve, more will be used under proper conditions.

The present jacklegs that are offered fall short of perfect performance. Each has one or more disturbing faults. If the good characteristics could all be incorporated in one type, more efficient and economical operation would result.

Performance records for one year at four different mines are shown in the table, which covers 1954.

When using both detachable insert bits and steel with chisel bit insert, it is difficult to offer a comparison of respective costs. The steel and bit cost about 55 pct more than the detachable bit. When gaged or damaged, some of this steel is cut and threaded for use with the detachable bits, labor being the only charge made for the conversion.

As a measuring stick for possible approximation of the steel cost, about 95 pct of the hoisted tonnage is drilled with 2⅜-in. bits and 1¼-in. hollow drill steel with a cost of bits and steel as follows:

Cost of bits and steel	$0.069 per ton or	$0.095 per ft
Bit cost	0.038 per ton or	0.047 per ft
Drill steel cost	$0.031 per ton or	$0.048 per ft

Jackleg drill labor cost per ton is about twice as much as the standard drill labor costs. Air consumption is approximately 50 pct less than that on the drifters. Repair parts costs are in favor of the jackleg. On the other hand, were it not for the light portable one-man jackleg, the conventional drill mounted on either a column or tripod would have to be used and two men would have to do the tramp and exploratory work now done with the jackleg. This would result in a much higher cost than is the case now.

Acknowledgment

Thanks are due to the officers of the Mining & Smelting Div., Eagle-Picher Co., for permission to publish this paper.

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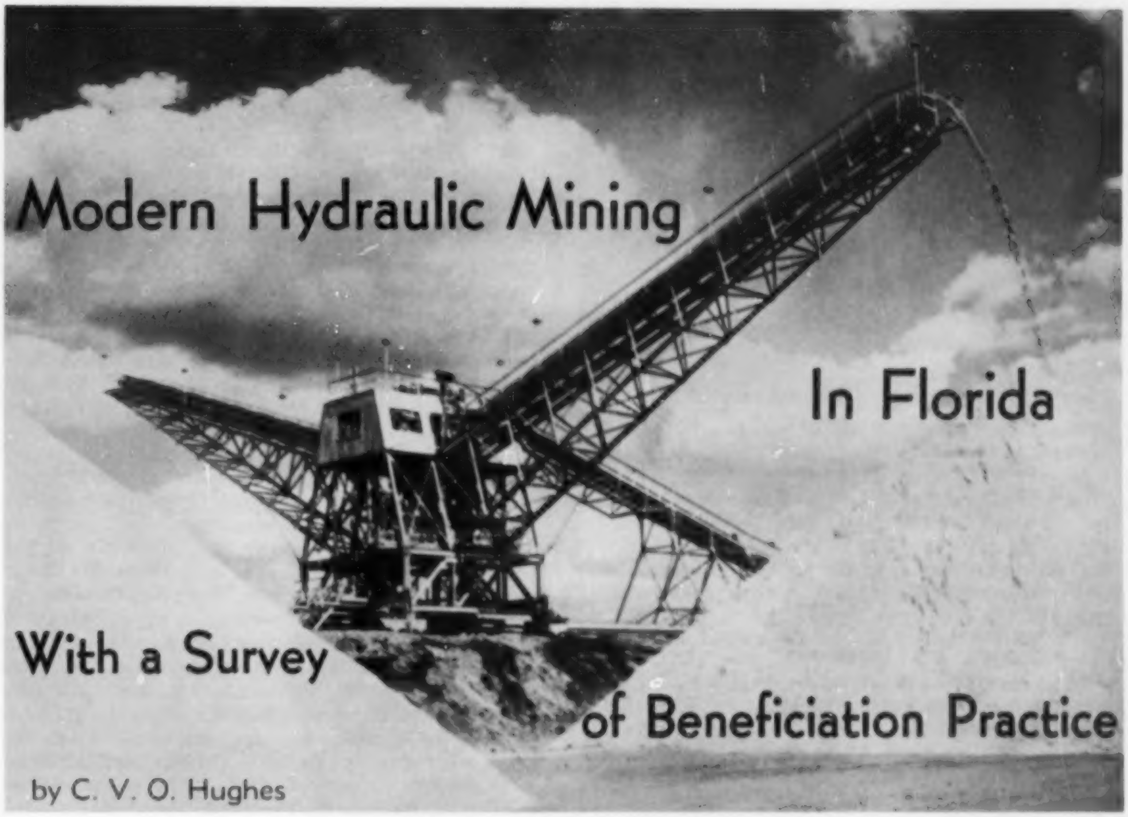

Modern Hydraulic Mining In Florida With a Survey of Beneficiation Practice

by C. V. O. Hughes

FLORIDA phosphate operations are unique in the ways standard mining equipment is made to meet specialized problems. Hydraulic mining and transportation has evolved in meeting three such special problems: 1) surface mining of a shallow, poorly consolidated but wet material; 2) high production rates, necessary because of low prices for phosphate rock in a highly competitive market; and 3) preparation of the value-bearing rock, or *matrix*, for washing and flotation.

The magnitude of the problems is better appreciated if the reader understands the size of operations in the area. The Florida phosphate field produces and ships about 10 million tons per year of phosphate rock. All of this has to be concentrated to its shipping grade, either by scrubbing and screening or by flotation.

Approximately 30 million tons of ore (matrix) must be fed to concentrating processes to produce the 10 million tons of shipping-grade rock. At least another 30 million tons of waste overburden must be dug to expose the 30 million tons of matrix. So there is an area digging more than 60 million tons total per year, setting more than 30 million aside as waste, and treating the remaining 30 million tons to produce 10 million tons of shipping-grade rock.

Hydraulic mining was selected not only because it was needed to meet local problems but also because it was easiest and cheapest to start; in part, simply because local conditions favored hydraulic mining. Florida is blessed with an abundance of water, both surface and subsurface. This factor in itself made hydraulic mining a natural selection. In addition, Florida's climate eliminates many troubles that might hinder hydraulic mining and transportation in winter. Piping can be left exposed; there is no need to drain lines for long shutdowns; and outdoor activities, such as hydraulicking, are feasible all year without costly protection for the men.

However, while hydraulic mining is perhaps the most unique feature of Florida's phosphate field, there are other outstanding characteristics of mining practice in this area—the concentrated use of large draglines, the use and reclaiming of large volumes of water, and the disposition of high tonnages of wastes (slimes and tailings). The processes of washing and flotation have unique features, too, although the plants greatly resemble similar plants in other mining fields.

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Summary of Flowsheet

The best method of description and explanation may be to start with digging of the ore (matrix) and thereafter follow the material through its transportation and treatment. The sequence of events is: 1) digging by dragline and placement near hydraulicking monitors, or guns; 2) gunning to break up the matrix, which is sluiced to the suction of the *pit* pump; 3) pumping from the pit pump through a pipeline, and one or more *lift* pumps, to the washer; 4) washing, scrubbing, screening; and 5) flotation concentration of undersize from the washing operation.

From the washer on, the material is separated into fractions. There are three final size fractions—*pebble* phosphate rock (recovered at washer), flotation feed, and slimes. The *pebble* or *washer rock* is a finished product; the slimes are waste. The

Bucyrus-Erie 650B walking dragline, with 17-cu yd bucket, digs in a pit near Pierce, Fla.

flotation feed, which is the size range between pebble and slimes, must undergo further separation by the flotation process. It is separated into concentrates, generally 32 to 35 pct P_2O_5, and tailings, generally 2 to 5 pct P_2O_5. The tailings are predominantly silica sand.

Draglines

To go back over the flowsheet in more detail, the first outstanding feature of mining in this field is the use of large draglines. Within, roughly, a 15-mile radius, there are 12 large draglines in operation, with nominal bucket capacities of 14 to 26 cu yd, and 14 smaller draglines with bucket capacities of 6 to 10 cu yd. These are owned by eight companies: American Agricultural Chemical, American Cyanamid, Armour, Coronet Phosphate (Division of Smith-Douglass), Davison Chemical (Division of W. R. Grace), International Minerals & Chemical, Swift, and Virginia-Carolina Chemical.

The larger draglines are the backbone of production; the smaller ones are generally used for auxiliary operations or in smaller pits. The large draglines, all of the Monighan walking type, have boom lengths of 175 to 235 ft, weigh 800 to 1600 tons, and have digging capacities of 1000 to 2000 cu yd per hr.

The phrase *nominal bucket capacities* was used above because increased use of lightweight buckets has raised the ratings. The 14-cu yd machines are able to carry 16 to 17-cu yd lightweight buckets; the 26-cu yd machine will carry a 30-cu yd lightweight bucket. The trend toward this upgrading of capacity is so pronounced that it may be considered one of the changed features in modernized strip mining in this area.

The most widely used large dragline is the Bucyrus-Erie 650B, with 175-ft boom and 17-cu yd bucket (or 20-cu yd lightweight bucket). Monighan walking equipment is used exclusively. The machine, in operating position, sits on a *tub* with low unit pressure on the ground. This helps both in soft, wet ground and in caving sandy overburden. Both conditions are found in the Florida phosphate field.

This machine, with 17-cu yd bucket, can dig an average 1100 cu yd per hr, including travel time. Peak capacity may be 1300 cu yd per hr. This depends upon ease of digging, depth of digging, and angle of swing. Since most of the mining patterns are practically identical, the angle of swing averages out the same for any pit over long periods.

The dragline sits at ground level, retreating along a cut 260 ft wide, the maximum for a 175-ft boom. The machine is positioned approximately at the centerline of the cut and digs both behind itself and alongside, on the bank side. This gives the retreating face a jogged appearance.

Overburden is piled back in the cut in either single-pass windrows, 260-ft spacing, or double-pass windrows, 520-ft spacing. In the double-pass windrow, overburden is stacked behind the dragline on the first pass, and as far out alongside as the boom can reach, i.e., at 90° to cut line, on the second pass. Although this method has many advantages, it does cover the toe of the matrix with close-piled overburden on the first pass. This leads to some contamination and to the loss of a little matrix on the next cut. (Soft ground, unusually wet weather, or poor pit dewatering accentuate the disadvantage.)

Gunning

With the overburden stripped, the matrix is lifted up to ground level and stacked in front of the *well.* The suction of the pit pump is in the well, which has been dug about 6 ft below ground level by bulldozer. A grizzly hangs above the pump suction, and forward of it, to trap out large rock that would stick in the pump suction or in the eye of the pump impeller. Grizzly bar spacing generally leaves 4 to 6 in. of clear space. It is safest to backstop this with a bridle arrangement, which is too open to be called

GUNNING: Dragline dumps bucket of matrix near well. At left is pit pump. Man in center holds handle of mudball gun, directed downward at grizzly (not visible). Streams of water from two main guns, at right and left, converge under bucket.

a basket, at the mouth of the suction pipe. The front end of the grizzly touches the ground, so that large rocks cannot pass underneath. The back end has a solid plate that prevents the rocks from going over. Oversize rocks must be picked off the grizzly by hand.

In the usual pit arrangement, two 2½-in. hydraulic monitors sit forward of the grizzly, one on either side. These two gun into the pile of matrix stacked ahead of them by the dragline. Another smaller monitor, generally 2-in size, sits alongside the grizzly. This is called the *mudball gun*. Its function is to break up larger agglomerations, or mudballs, that reach the grizzly and cannot go through. Pressure at the gun nozzles is generally not lower than 80 psi and not more than 130 psi. Pressure pumps actually develop up to 205 psi, but line and fitting losses result in considerably lower pressures at the nozzles.

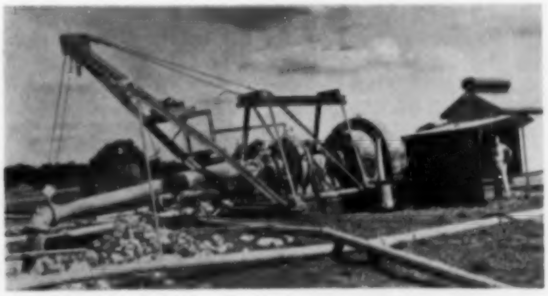
The back end of the grizzly has an upward curve so that the mudballs and rocks can be swept up and allowed to fall back, helping to break them. The mudball gun also serves to drift heavier feed up to the grizzly. Here it acts more as a kicker than as a disintegrator. The heavier feed may often be no denser than normal but may lack slimes.

Pressure pumps are located at a source of clear water, and high-pressure waterlines bring the water to the pit. Pumps are of the horizontal shaft centrifugal type or the multistage vertical shaft turbine type. The latter is gaining favor because it is self-priming, saving labor costs, and submersible. It is also fundamentally a high-efficiency pump.

Good gunning practice means a minimum of troublesome oversize and a maximum percent solids in the slurry to be pumped. Both these factors—efficiency of pumping the slurry and ratio of solids to water—affect the cost of transporting the matrix to the washer. Unfortunately gunning is considered a relatively unskilled job and often gets insufficient supervisory attention.

Pumping

Once the matrix has been broken up and sluiced to the pit pump's suction, the problem is one of hydraulic transportation, concerning pumps, pipelines, and fittings. The pumps must be roomy enough to pass the maximum size rock that gets through the grizzly, about 6 to 9 in. diam. They must have ample capacity to handle away gun water, about 5000 gpm, plus solids, about 10 cu yd per min, in



PIT PUMP: Suction pipe 14-in. pit pump goes down into well at left. Note rubber flexible connecting pipe into pump suction. Above dark-stained end of rubber flexible is an electric motor, gearbox, and drum to raise and lower pump suction in well. To right of pump, 600-hp motor is shielded. Only pump and motor are on the sled. Photograph from Pettibone Mulliken Corp.

Key Mining Units:

Draglines, 14 to 26-yd—

Typical: Bucyrus-Erie 650B, 175-ft boom, 17 to 20-yd bucket.

Gunning—

Typical: Two 2½-in. monitors with 2-in. mudball gun.

Pumps—

Standard: 14-in. alloy construction pump with 16-in. fittings, 500 to 800-hp motor.

Pipelines—

Standard: 16-in. diam; various construction, seamless tubing, Naylor-type, spiral or straight weld, in 40-ft lengths.

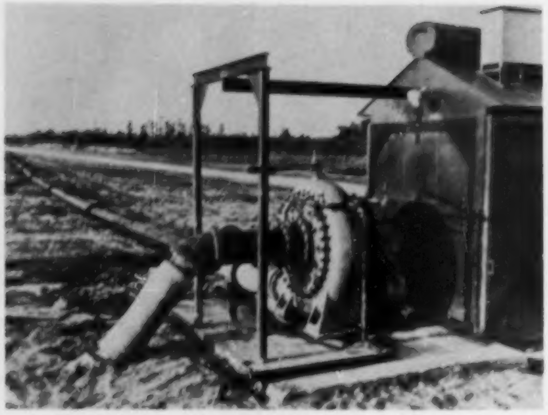
most installations but up to 15 cu yd per min in at least one instance. Actually the limiting factor is the largest piece to be passed. The pump must be so large dimensionally to pass 6-in. rocks that it inevitably has a potentially high capacity—normally 50 pct or more in excess of the volume it is called on to handle.

The standard pump in the field now is a 14-in. pump, capable of swinging a 38 or 40-in. diam impeller at 500 or 600 rpm. Since these pumps are direct-coupled to electric motors, the actual top running speeds are 495 or 585 rpm, depending on whether the motor is 14-pole or 12-pole. A visitor might be confused to see a *14-in.* pump with 16-in. suction and 16-in. discharge. Today, with the 16-in. pipeline standard, pumps are made to fit at suction and discharge without transition pieces. But internally the pump may be equivalent only to a 14-in. dredge pump, that is, with an internal clearance shroud-to-shroud of about 10 or 10½ in.

There are in fact some true 16-in. pumps in use here. These are giant 16x52 pumps, taking about 900 hp at load. But the 14-in., which has come into its own since the war, is now the workhorse of the field. It has ample capacity and lacks only about 1½ in. of the internal clearance of the 16-in. It might take three 14-in. pumps to achieve the rate of two 16-in. pumps, but the choice is one of number of pumps rather than of capacity or performance. In fact, the 14-in. gives somewhat more efficient performance because it is not operating so far below its peak efficiency point as is the 16-in.

The pumps must meet demands other than physical size and capacity. They must be ruggedly built throughout wetted parts, shaft, and bearings to withstand vibration and shock at high horsepower loadings. In addition, because of abrasion, they are made of wear-resistant metal. There are still uses where pump iron or Meehanite gets by. But increasingly, Ni-Hard and high chrome iron (26 to 28 pct Cr) are used. While all these metals, and some alloys, are still in use and while all have their place and their boosters, high chrome iron has found more and more favor in the severest duties.

It is perhaps best to drop the discussion of pump design at this point. Opinions diverge further and further with regard to impeller design, use of liner plates, best fit of suction plate to impeller to minimize wear, and the best manner of sealing. It is enough to say that solids pumping is not nearly the



LIFT PUMP: This 14-in. Pettibone Mulliken lift pump is on concrete base, instead of steel sled, because it is in semi-permanent location. Discharge line shows flanges every 40 ft; service road parallels line to right. Suction pipe was buried for structural stability.

exact science that clear-water pumping is. Science gives way to art, and facts to opinions.

Pumps are compared on clear-water performance curves. But once they start handling solids, there are many poorly measured variables to contend with: variation in percent solids, in ratio of coarse to middle sizes to slimes, in stratification in the lines. It can be said here only that practice has narrowed down the field of choice of pumps, although different people may have somewhat different theories as to why it happened that way.

To summarize, the typical modern solids-handling pump in the Florida field is a 14-in. pump with 16-in. suction and discharge. It is direct-coupled to an induction motor (wound-rotor, variable speed) and runs at a top speed of either 495 rpm or 585 rpm. It is capable of taking up to a 40-in. impeller but may turn anything from a 34-in. to 40-in. impeller depending on its speed and service. It delivers 7000 to 8000 gpm of slurry at 25 to 45 pct solids; the percent solids depends on gunning at the pit. The maximum size rock handled is generally not much more than 6 in.

Most of these pumps, driven by 500 to 800-hp motors, handle 500 to 600 cu yd per hr of matrix. Occasionally they may pump from 800 to as much as 1000 cu yd per hr; in this service, they must have not less than 800 hp driving, and the load may go to 900 or 1000 hp. Most of the pumps develop from 140 to 160 ft of total dynamic head; the largest may develop as much as 210 ft tdh.

Pipelines

Pipelines for matrix transportation are now almost all 16-in. diam. A few years ago maximum length of matrix or *rock* line was 2½ to 3 miles. Today there are lines 4 or 5 miles long. The central plant is getting bigger and includes a costly flotation plant. Economics now favor transporting raw material rather than moving the plant. Various makes, types of construction, and thicknesses and analyses of steel pipe have been used. Lack of availability of preferred kinds of pipe during the war led to considerable diversification and experimentation.

Practice today is favoring the heavy-wall (5/16-in.) seamless tubing, of abrasion-resistant (AR) analysis steel. Many other kinds of pipe have been used with considerable success, and some are still used. Naylor-type, spiral-weld, and straight-weld tubing are all still in use. Many still have 1/4-in. wall thickness. But the trend at present is to heavier walls and seamless tubing. Standard length of pipe sections is 40 ft.

In the 16-in. pipe velocities generally are held between 9 and 11 fps. However, in pumping at high rates, or in high-pebble low-slime matrices, velocities have reached 12 to 14 fps, possibly even somewhat higher at times. Such high velocities mean accelerated pipe wear and high line resistances. Too low a velocity leads to accentuated segregation of sizes, to sedimentation in the line, and eventually to a plug-up. In one 6-mile line (not a matrix line), a velocity of 7 fps is used to transport sized flotation feed. Even with this material the line has been plugged several times when the feed has been deficient in fines. Critical velocity for most matrix material is about 9 fps and may be appreciably higher for sandy matrix with high pebble content.

Most pipelines are joined by bolted steel flanges, and the joint is sealed by a gasket. However, there is some objection to the cost of welding flanges on the pipe joint ends, and also to time and cost of breaking joints in replacing a joint or in turning pipe. Consequently, Victaulic and Dresser couplings are used on some lines, but results are not immediately conclusive. Rough and careless handling can make any joining method look bad at times. The cheapest, quickest, and most trouble-free joining method, under normal handling, remains to be proved.

High-pressure rubber flexible lines are used for joining both suction and discharge to the pipelines. At turns in the line, both cast and fabricated steel elbows are used. For very small turns or kinks small wedges of pipe with flanges close together are used, locally called *Dutchmen*. It is, of course, preferable to keep the pipeline as straight as possible in both horizontal and vertical planes. But while elbows and Dutchmen can be overdone due to sloppy alignment, they do serve a purpose in relieving strains at necessary changes in direction.

To control lift pump speed some operators use a pressure-sensing device in their pipelines. The theory here is that because of changes in pit pump speed and perhaps also in line resistance, due to changing feed, lift pump speed must be varied to stabilize line conditions. Certainly it is not desirable to have surging pressures and velocities in a long line. Uneven delivery at the washer end is at best an inconvenience. However, it could be corrected with a surge bin at the washer.

More serious is a condition of shock that develops in the lines, especially where more than one lift pump is used. An old rule of thumb was one pump to every mile of pipeline. Today, one pump carries about 1½ miles of pipeline with normal matrix. Sandy, high-pebble matrix requires closer spacing. Only the very largest diameter pumps, such as the 16x52 previously mentioned, will pump successfully at 2-mile spacing. So the normal pumping setup today is one pit pump followed by one or two lift pumps. It is at the lift pumps that trouble may develop.

A condition of water hammer may burst a pipe section or, more seriously, split a pump shell. What causes these pressure surges is not clear. One factor, certainly, is air in the lines; whether it is the only important factor the writer is not bold enough to say. At any rate, if speed regulation at the lift

pumps is meant to guard against this danger, its efficacy is doubtful.

Observation indicates that the damaging pressure surges are sudden. It is the writer's opinion that, even if power were completely cut off the pump, its inertia would prevent it from compensating quickly enough for such a surge. The reader should be aware that this view is not universally held; he is free to form his own opinion.

Virginia-Carolina Chemical Corp. operates one matrix line with variable-speed lift pump, one with constant-speed lift pump. Neither is free from pressure surges; neither has a consistent advantage over the other. The company also operates one 6-mile screened feed line without pressure relief, and one 4½-mile screened feed line with pressure relief. The line without pressure relief operates more smoothly. However, other features about the two lines are dissimilar, and there is always doubt as to which different factor accounts most for the difference in operational results.

Whether or not pressure-regulated speed control of lift pumps adequately reduces line shock, it does smooth out the flow of the slurry in the line. Another device of value is to provide air bleeds at strategic locations—so long as they do not breathe and become also air intakes. They have check valves but check valves are known to seat poorly at times, particularly with solids on the seat.

Perhaps two other precautions are more important: 1) Operate the pit so that the pit pump does not suck air in the first place. 2) Space lift pumps so that there is no danger of a swing to negative pressure at the suction side, i.e., so that there is adequate pressure but not excessive pressure at the intake side.

Phosphate Field Beneficiation Operations

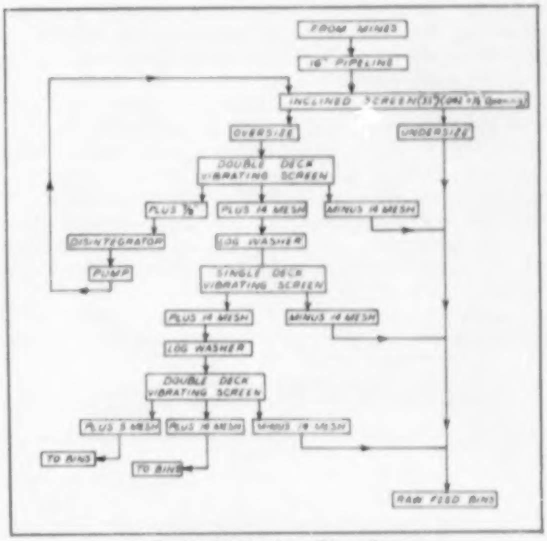
Washer

This brings the mined material to the washing and concentrating plant. The solids have been in the line an average of 8 to 10 min for every mile traveled. The larger pieces, traveling more slowly, have been in the line longer. They have tumbled and rolled in the turns in the line and have been thoroughly tossed about in one or two lift pumps. This illustrates one of the secondary advantages of hydraulic transportation. Had a dry carry been used, it would have been necessary to provide a soaking bin and a blunging unit of considerable size at the washer to achieve the same treatment the solids have undergone in hydraulic transportation.

At the washer the first job is to separate the incoming matrix into three portions: fines going to flotation, middlings to be scrubbed and screened, and coarse to be beaten down by a size reduction unit. The exact points of division vary from company to company. Fines are usually screened through 14 or 18 mesh, although this separation has been made as coarse as 10 mesh and as fine as 20 mesh. The coarse end is scalped off at about 1 in. (more usually, ¾ in. or ⅞ in.). This leaves the middle portion ranging from about 14 mesh to ⅞ in.

It makes little difference whether the coarse is scalped first or whether the fines are screened through first. Both methods are used. Present practice favors eliminating the bulk of the fines first, on a long stationary inclined screen. This is generally a punched-plate slotted screen, with slots lengthwise to flow. Here most of the water and the −14-mesh is separated out, and the +14-mesh then goes to a scalping screen where the +⅞ is taken off and sent to a *hog* (hammer mill or submerged rotary disintegrator). When the +⅞ is broken up it is recirculated to the stationary slotted screen. This closes the circuit for the coarse fraction.

The middlings, +14-mesh and −⅞, contain the valuable *washer rock* fraction. In this size range, the phosphate particles predominate, and a satisfactory product can be made by screening alone. It is necessary only to break up the mudballs and to wash off clinging fines from the phosphate particles. The resultant clean rock is then a finished product. It is generally separated into two size fractions, the finer one, −5-mesh +14-mesh, being of somewhat higher grade than the coarser one, +5-mesh −⅞-in.

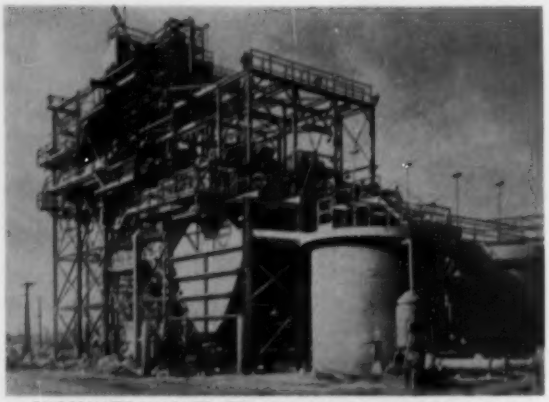


Typical Washer Flowsheet

These middlings, after the screening out of the fines and the scalping of the oversize, are washed on a screen, rotary or vibrating, and then go to a scrubber. In most washers today this means a log washer. However, rotary scrubbers are still used. They are particularly effective for a sandy type of matrix. Where there is much clay or *mudballs* the log washer is preferred. After scrubbing, the middlings are screened. They may or may not go through another stage of scrubbing or log-washing. Possibly only the coarser fraction may require this.

In either case, if more scrubbing is needed, there will be a dewatering and washing screen after the first log washer or scrubber. If all the washer rock is to be rescrubbed, this screen will be 14 mesh. If only the coarser portion is to be rescrubbed, the screen will be 5 mesh. After the rescrubbing the washer rock is screened again and conveyed to bins from which it can be loaded into railroad cars or dried. This depends on whether dryer is in the same plant area as the washer or at another point.

The phosphate rock washer is not unlike the sand and gravel screening plant used for supplying



PHOSPHATE WASHER: This plant is all-gravity flow. Mine feed flows over screens, through log washers. Cylindrical tanks hold —14-mesh. Catenary bin holds phosphate pebble.

aggregates to contractors. It has a feed capacity of 500 to as much as 1000 tons per hr. It produces at least 500 tpd of clean washer rock and may produce 2?00 tpd. This variation in production is due more to differences in pebble content of different matrices than to differences in feed rate to the washer.

Most washers are built with two *sides*, i.e., two parallel paths with duplicate machinery in the two paths. The load is normally split in half at the headbox. When some major piece of equipment breaks down on one side, the full feed load is temporarily transferred to the other side. One washer is built with three parallel paths, so that two thirds of the washer can still be run while repairs are effected on one path.

Modern features found in many washers are low-head vibrating screens, repulping screens, alloy steel screen cloth and punched-plate, rubber-lined launders and chutes, enclosed unit gear drives on log washers, and product bins located alongside tracks rather than over them. This last gets away from spillage on tracks and permits more even loading of cars. Carloading is by inclined belt. Since the bin is located lower, part of belt cost can be figured against elimination of the elevator needed for overhead bins. Wet cyclones are another modern feature, for dewatering and slime separation in some of the washers. In the phosphate field, as elsewhere, wet cyclones are used more and more for various dewatering, thickening, and classifying jobs.

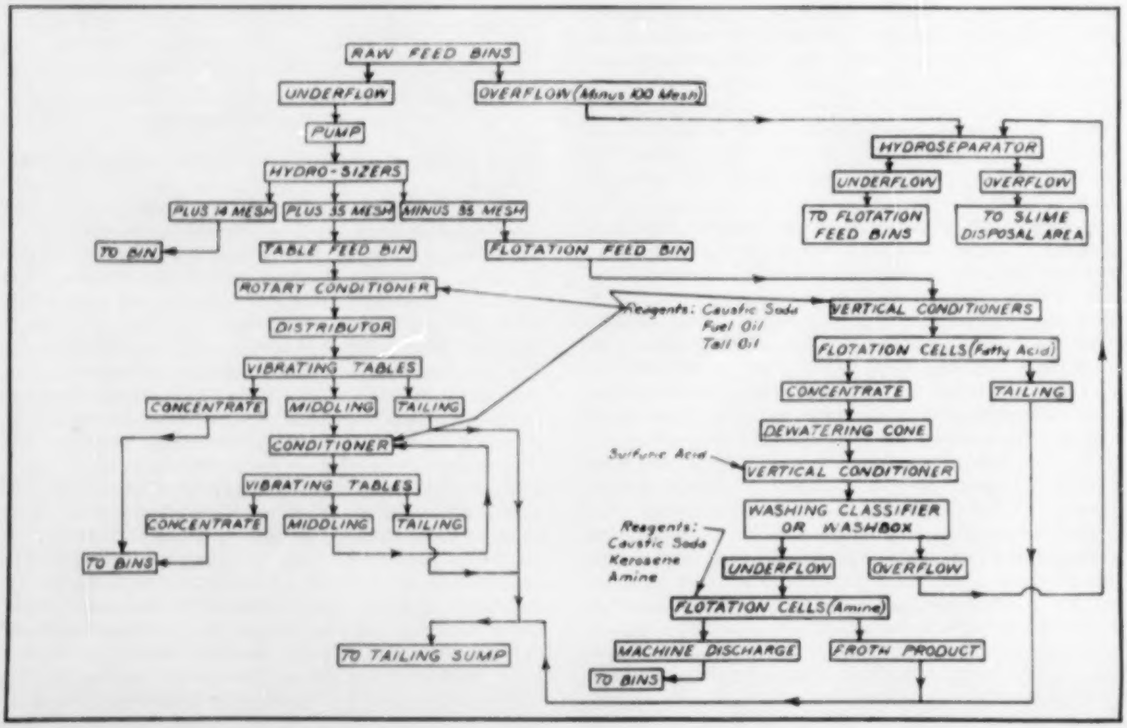
Flotation

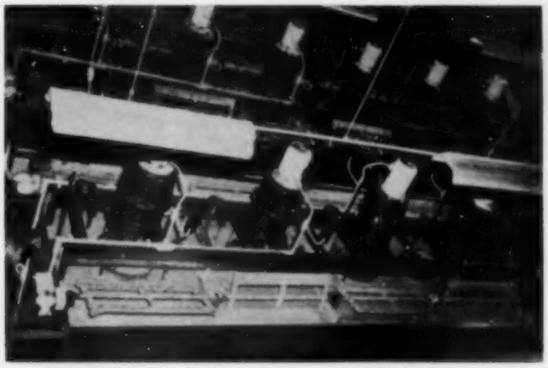
From the washer the undersize, —14-mesh, goes to the flotation raw feed bins. Here there is an initial desliming by overflow. The overflow goes to a hydroseparator, where fine cell feed is recovered.

Raw feed is pumped from the bottom of the bins to Fahrenwald-type hydraulic sizing units, generally Dorrco sizers. Here the feed is separated into several size fractions and at the same time is further deslimed. In most plants, the various pocket fractions are recombined into two feed sizes, the coarser —14 +35-mesh feed for tables, spirals, belts, or coarse feed cells and the finer —35 +150-mesh feed for standard flotation cells. There is some merit in recombining so as to have two different sizes of cell feed, to be handled in two different banks of cells, but opinions differ on whether there is enough merit to maintain the separation throughout the plant.

After the sizing and desliming, the flotation feed goes to prepared feed bins. From here it is generally pumped to spiral classifiers where the feed is dewatered before going to conditioners. In the de-

Typical Flotation Plant Flowsheet





FLOTATION CELLS: This shows a four-cell bank in foreground and a six-cell bank in the background, a standard setup, although one company uses five-cell banks for its fatty-acid float. Photograph from International Minerals & Chemical Corp.

TABLES AND SPIRALS: The 15 Deister diagonal-deck 6x15-ft tables in this plant are decked and riffled with aluminum. This has given better performance and less maintenance than other decking materials. Humphreys spirals, at left, are used in parallel with the tables.

watering, there is a final desliming of the feed. All overflows (raw feed bins, sizers, prepared feed bins, spiral classifiers) and spillages report to the hydroseparator for reclaiming of fine cell feed.

The dewatered feed from the spiral classifiers drops into conditioners where pH is adjusted with caustic to about 9.0 or 9.5, and an anionic collector containing fatty acids is added; tall oil is most commonly used. Fuel oil, 18 to 20 A.P.I. gravity, is used as an auxiliary collector and also to stabilize the froth. This fatty acid float is rarely used to make a finished cell concentrate nowadays. It is simply a primary flotation to make a rougher concentrate. The cell tails from this float are end tailings, but the concentrates go on to further steps.

However, for the tables (or spirals, belts or coarse-feed cells) the fatty-acid conditioning is only one used. The conditioning serves to make the phosphate particles cling to one another, with air entrapped in the voids. These effectively larger and lighter-density agglomerates are separable, by virtue of apparent size and apparent density differences, from the sand.

This explanation applies better to the tables, spirals or belts. The cells now also being used for this separation depend on heavy agitation and high lifting power. They are a shallow type of cell with considerable excess air introduced. Some are, in fact, air cells without mechanical agitation.

It may be puzzling to see so much diversification in methods of concentrating the coarser fraction of the flotation feed. The writer has no facile explanation; there seem to be strong proponents of each method and there is no conclusive evidence as to who is most nearly right.

Virginia-Carolina Chemical Corp. uses tables, and it is believed that these make the sharpest separation. However, tables do have a relatively high first cost per unit of capacity and require much costly floor space. Their operating costs, including maintenance such as deck and riffle replacement, are higher than for simpler equipment. Whether their sharper separation more than pays back for added costs is not an easy question to answer. Some believe so; others do not.

In the matter of cell flotation of the finer flotation feed, there is much more unanimity. It has previously been mentioned that the fatty-acid float is only the first step of the double float now almost universally used. The rougher concentrate from the fatty acid float is de-oiled with sulfuric acid; the oil is then physically separated with water in a rinsing box.

After rinsing, the de-oiled rougher concentrate is thickened, and at the same time cleaned still further of oil in a screw classifier. It is then conditioned, at an adjusted pH of about 7.4, with either a straight amine or a partially neutralized amine salt, generally simply called an *amine*. Kerosene is also used in filming the activated surface. It is an auxiliary collector in this float, as the fuel oil is in the fatty acid float. Reaction here is with the sand grains, and the sand is then floated away from the phosphate.

The amine float permits the production of a cell concentrate with only 3.0 pct *insoluble* (silica). When the fatty-acid float alone was used to produce an end product concentrate, 6.0 pct insoluble cell concentrates were common. If less sand than this was pulled into the concentrate, loss of phosphate to tails was excessive.

Reagents, conditioning methods, and types of flotation cells vary somewhat from company to company. However, the overall pattern is very similar, and there is not any really marked difference in manner of flotation or in results obtained in cell flotation of the finer feed fraction by the double float.

Of course, it should be realized that a small difference in results may mean a great deal in cost where such high tonnage is involved. If, for instance, a flotation plant is handling over 2 million tons of feed per year, an added cost of 5¢ per ton means over $100,000 per year. Where every penny saved means a cost cut of $20,000 per year, small differences assume significance.

This represents only the quickest summary of the flotation process. But it is not the purpose of this paper to cover flotation, except as it relates to overall mining practice and mining problems.

Special Problems

Tied together are three major problems: 1) transporting and settling slimes from the washing and flotation steps, 2) disposing of flotation tails, and 3) clarifying and reclaiming large volumes of water needed for both washing and flotation. To these might be added a fourth: maintaining public relations by keeping receiving streams clear and confining wastes to areas where they cause no problems.

The relationship between the first and third problems is clear. Separating out slimes by settling

means that clarified water will be available for re-use in the plant. Differentiation of the two is a matter of viewpoint and of degree. Settling out the bulk of the slimes might be good enough purely as a measure of disposal. But even slightly milky return water is a reagent consumer, and upsetting in efficient operation of a flotation plant. So getting clear return water goes a little beyond disposing of the bulk of the slimes. Here is where the aforementioned saving of a penny per ton, i.e., by having clear return water, may assume importance.

The tails, in present practice, are used to reinforce and build up the dams around settling areas. This is where they tie into slime settling and water clarification. Virginia-Carolina Chemical Corp. has perhaps devoted the most persistent attention to building tailings dams around slime settling areas. As a result of five years of constant attention to this, the company now has three areas totaling 900 acres completely enclosed by tailings; the weaker dams on another 600 acres are reinforced with tailings.

Once the necessity for large, well dammed settling areas is accepted, tails become welcome rather than presenting a problem. They are needed for the dams. Even though a large flotation plant produces 1 or 2 million tons per year of tails, there may be times when more tails are needed than are available for dam building.

Virginia-Carolina Chemical Corp. builds a combined total of 5 or 6 miles of tailings dam each year at the company's two flotation plants. This length of dam averages 6 ft high. By repeated passes it can be carried upward for as much as 40 ft in one place. Of course, pumping tailings costs money but to replace tails with constructively placed fill dirt costs more. Hydraulically placed tailings also make a more stable structure than does most fill dirt found in local Florida borrow pits.

The settling areas are, in general, mined out pits. At first they are enclosed only by dirt dams cast by the big draglines. Later these dams are reinforced or built higher. The mined-out pits do not, however, supply enough settling area. It takes no studying to understand that when mining starts at a new plant there are as yet no mined-out areas. Adequate initial settling area must be dammed up on virgin ground. The location is, of course, selected not only for geographical reasons, but so as to be on unmineable land.

A modern flotation plant requires not less than 500 acres of settling area. This is a minimum; it takes nearly 1000 acres, properly dammed and in full use, to provide sufficient flexibility and safety for comfortably trouble-free water reclaiming. This means that considerable virgin area must be dammed in the opening of a new mining area. Further, all mined-out areas must be properly enclosed and promptly brought into use for slime settling.

Settling areas must be large enough, and have big enough spillways, to handle a total load of 25,000 to 30,000 gpm. This volume of slime-bearing water may only contain 2 or 3 pct slimes but the contained slimes, settled out, will fill up about 2000 acre-ft of space in a year. This is the magnitude of the problem presented by a large modern washing and flotation plant.

With adequate settling area space, the problem of storing slimes is solved. The problem of getting most of the clarified water back to the plant requires additional effort. Some settling areas may of necessity be so located that returning clarified water is too costly. Drilling a deep well and installing and operating a deep-well pump near the plant may prove more economical.

In general, however, the phosphate mining companies make every reasonable effort to re-use clarified water from the slime settling areas. This requires careful long-range planning of the areas and the direction of flow through them. At times, it also requires the installation of some low-head, high-volume pumps to lift slimes up into a high-elevation area or to lift return water up out of a low-elevation area.

The various operating companies are good water conservationists, for many reasons. One reason is that deep well pumps are rather costly to run; it is usually cheaper to reclaim water. A second reason is that reclaimed water is less of a reagent consumer and less likely to promote corrosion of plant equipment. Deep-well water here is high in hydrogen sulfide and requires aeration. It is also hard water, borne by the Ocala limestone. A third reason is that with a closed circuit any malfunctioning of the settling areas can be detected at once and corrected. Where receiving streams are heavily used for fishing, and even support some commercial fishing camps, this is good sense and good public relations.

This emphasizes the fourth potential major problem. It is encouraging to note that this problem (waste releases into streams) has been met and solved in an increasingly effective manner in the last five years. It is now recognized that mineral slimes are not directly damaging to fish life, except where releases are heavy enough to blanket the stream bottom and cover up food and spawning beds. Long-continued releases that cut off light penetration can reduce plant life and lead fish to move out for lack of this type of food. Generally, however, there is little real damage except from an esthetic standpoint. Nevertheless, the companies take this seriously enough to invest heavily in dams, spillways, pumps, and pipelines to control water flow and prevent releases of solids-bearing water.

General Outlook of Field

As with the digging, transporting, and concentrating operations, the problems of slimes disposal, water reclamation and tailings disposal are large-volume problems. Large-volume problems have the disadvantages of slow solution, of needing high initial investment, and of requiring long-range planning to stay under control. Once adequate solutions are developed they have the advantages of low unit cost, of eliminating recurring short-term crises or emergencies, and of allowing time for gradual revision and improvement.

The Florida phosphate field has slowly evolved adequate solutions to its problems. There is, of course, still much room for improvement. Where a penny a tor is worth much attention, it is neither wise nor safe to be complacent. Ahead of the field lie many needed changes in substituting power for labor, in automation, and in redesign of machines and processes for still greater efficiency. Changes may appear slow at times, but it must be remembered that such large investments cannot be quickly scrapped. The profit margin is relatively small and will not support too rapid obsolescence. Considered from this viewpoint, the changes in equipment and technique within the last ten years have been remarkable.

Do's and Don't's on Belt Conveyor Maintenance

by R. U. Jackson

BELT conveying is a method of transportation that requires proper servicing and maintenance if completely economical results are to be obtained from the system.

With a trucking system, it is common practice to deliver the trucks to a servicing station each day or at the end of each shift. With railroad transportation there is a similar procedure. Sufficient credit is seldom given to this periodic inspection and maintenance procedure, yet it is the key to the successful operation of trucking and rail haulage systems.

How about the belt conveyor transportation system? Here is a system that requires no operator for each individual unit. It requires only a main switch and an adequate sequence interlocking system, and the system is so simple to operate that maintenance is considered as only a casual requirement—nothing is done about it until after trouble has developed.

Start with housekeeping.

The beginning and end of proper belt conveyor maintenance is *good housekeeping,* which does not mean the cleanup of a conveyor line once each month or two, but maintaining a clean conveyor system at all times.

When a conveyor system is installed, the manufacturers of the equipment and belt will furnish adequate operating and maintenance information and bulletins or drawings, listing component parts, accessories, etc. Too often, however, this information is filed in the purchasing or engineering offices and the maintenance men are left with nothing of real value to help them with their work. One belt man properly equipped can patrol a belt line of 1½ to 2 miles to lubricate idlers and drives, maintain belt and conveyor frame alignment, detect sticking idlers, and maintain an unobstructed right-of-way.

Actually, maintenance begins with selection of the equipment and belt that is properly designed for the service required, remembering that over-design is just as foolish and expensive as under-design. Both will work, for a time at least, but neither will be economical.

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Conveyor belt carrying refined muriate of potash from refinery to warehouse at the Carlsbad, N. M., plant of Southwest Potash Corp. Note attention to housekeeping detail—safety sign, adequate lighting.

Belt selection is important.

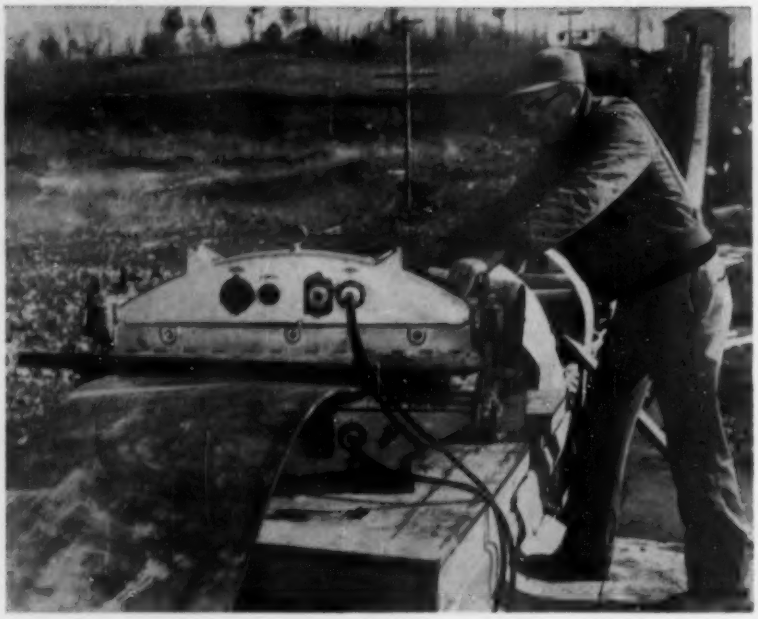
Selection of a proper conveyor belt is of utmost importance. A belt required to handle coal from present continuous mining equipment can be designed on the basis of tension requirements, with a proper balance between carcass and cover, to obtain lowest cost per ton. A belt required to handle mine-run coal where large lump must be handled requires a much heavier carcass in order to produce proper body to withstand impacts. The covers must also be designed for protection against this impact, even though impact accessories are incorporated in the machinery design. Here again, the belt carcass and covers must be in balance to insure low cost per ton.

How large a motor?

Where a long or steeply inclined belt is installed, with design data indicating the need for a 75-hp motor, it is not playing safe to install a 150-hp drive and motor. It is the most unsafe thing to do, as this

Shock pad conveyor belt. The pad yields to sudden, extreme impacts and pressures—protecting the cover from puncture or breakage and preventing rupture of the carcass.

Mining



Construction of a conveyor: After the conveyor belt is spliced, it must be vulcanized together. Here the portable conveyor is locked. This belt is part of the mile-long conveyor system at the Catskill, N. Y., plant of Alpha Portland Cement Co. The conveyor will carry limestone at the rate of 300 tph from screening station to storage area where it will be crushed.

overload starting power will certainly not help the belt. A high tension belt should not be started with across-the-line control. For belt protection, some form of controlled acceleration starting should be used. Across-the-line starting is permissible for low power conveyors, where the belt is of minimum ply construction but greatly understressed in operation.

Choose the proper pulley.

Only use dual pulley drives or tandem pulley drives where they are required to reduce belt tension and thereby permit the use of a more economical belt carcass. Dual or tandem pulley drives should never be used without being properly lagged, preferably with grooved rubber lagging. If there is a wet or frosty condition, the grooved lagging will definitely help eliminate belt slippage at the drive.

For better and safer operation of long horizontal or slightly inclined belts, a gravity type of automatic take-up should be located directly behind the drive to maintain proper slack side belt tension. On inclined belts over 13° to 14° the return belt itself acts as the counterweight and usually produces sufficient slack side driving tension. On this type of slope the automatic takeup can be economically placed at the tail end.

Although present standard practice calls for a pulley face 2 in. wider than the belt, for mine conveyor service in particular, no pulley face should be less than 4 in. wider than the belt. No mine conveyor installation can be made perfect, and this precaution doubly insures against belt damage from a wandering belt.

Lubrication, too!

Troughing and return idlers require lubrication but should never be overlubricated. Unless the conditions are very wet or very dusty, lubrication once in six months is sufficient. The safest and most economical method for determining the proper lubrication period is to take an idler out of service at specified intervals, take it apart, and examine it.

Return idler location is important. Idlers should be located a distance below the conveyor stringers to be more easily inspected by the belt man. This will also permit the belt man to see readily how the return belt is training. Better training will result from return idlers spaced at 12 ft than at 8 ft. The added pressure will permit each idler to do a better steering job with fewer idlers to maintain. Adequate side clearance between return belt and conveyor frame is just as important as the wider conveyor pulleys. When making the installation, all conveyors should be properly aligned by transit, and spads should be placed so that a check on the alignment can be made at frequent intervals by the belt man.

Splice it right!

One of the frequent causes of poorly trained belts is in the belt splice itself. Where mechanical belt splices are used, the only safe method is to establish an average belt centerline at least 15 ft back from each belt end to be spliced, then cut the belt ends at true right angles from these centerlines and match the ends carefully. Never square from the belt edge to make a splice because this belt edge is seldom true.

Remember the fire hazard.

The items mentioned to this point have included mostly the physical properties of the conveyor equipment itself, all of which should be given serious consideration, as they definitely affect the economical and safe operation of the conveyor system. Also, these physical features of design are a contributing factor towards the elimination of the ever-present fire hazard.

As this fire hazard must be considered as an important factor in mine conveyor design, additional features must be considered necessary for successful installation of a belt conveyor system. Primarily, this involves the use of adequate electrical control equipment.

Uranium Deposits in the Black Hills

Since uranium ore was discovered in the Black Hills in 1951, prospecting and mining activity have increased steadily. Recent exploration by the Government and by private industry has resulted in discovery of several orebodies of 10,000 tons or more. Structural features are believed to exert important control on localization of ore deposition, and surface mapping of these features provides a means of determining potentially favorable areas of a few tens of acres.

by John W. King

URANIUM ore was first discovered in the Edgemont district of the southern Black Hills in the summer of 1951. The discovery was not made known for some time, but after the news leaked out prospecting became intense, and several hundred claims were staked in the spring of 1952. The Hot Springs Sub Office of the Atomic Energy Commission was established at that time and airborne radiometric surveys were commenced by the Government and by private companies. During the succeeding summer another important discovery was made by private airborne surveys in the northern Black Hills, and the area favorable for uranium ore was expanded many times. Between that summer of 1952 and the present, many individuals and groups have explored, developed, and exploited their claims until now uranium ore is produced in significant quantities and substantial reserves have been developed.

The Black Hills portion of the geologic map of the U. S. issued by the U. S. Geological Survey is shown in Fig. 1. Sedimentary formations are exposed as a series of cuestas and hogbacks in a roughly annular pattern with the older sediments resting on the pre-Cambrian core, which is exposed in the eastern and southern portions of the dome.

The South Dakota-Wyoming state line bisects the area from north to south. The Cheyenne River crosses the southern tip of the Black Hills and the Little Missouri bounds them roughly on the north.

Headquarters of the AEC in the Black Hills is the Sub Office at Hot Springs, S. D. An ore buying station is located in Edgemont, 28 miles to the southwest, where a mill is presently under construction. The area of original uranium ore discovery and of principal activity in the southern Hills is a few miles north of Edgemont. Several areas of anomalous radioactivity have been noted between Dewey, S. D., and Newcastle, Wyo. A limited amount of ore has come from the Dewey area and private exploration is active there.

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Discussion of this paper, TP 4131 I, may be sent (2 copies) to AIME before March 31, 1956. Manuscript, Feb. 14, 1955. Chicago Meeting, February 1955.

Fig. 1—Black Hills portion of USGS geologic map of the U.S.

The Carlile deposit, largest producing mine in the northern Black Hills to date, lies northwest of the Belle Fourche River near the western extremity of the Hills. Two of the larger known orebodies of the area are located near the Little Missouri River where a small window exposes the favorable stratigraphic horizon of the Fall River sandstone. Small production has recently come from Barlow Canyon, near Devils Tower, Wyo., Fig. 2, and numerous areas of anomalous radioactivity are known in the vicinity. Three producing deposits and scattered radioactivity are found along the state line east of Aladdin, Wyo. Several areas of weakly anomalous radio-

The Transactions papers appearing in Mining Engineering during 1956 will subsequently appear in AIME Transactions Volume 205, and may be permanently referenced to that volume.

Fig. 2—Aerial view looking westerly, showing Devils Tower with Missouri Buttes in background. Several producing mines (Carlile, Barlow Canyon, and New Haven) are in this vicinity.

activity are known near Sturgis, S. D. The eastern margin of the Hills shows little encouragement in spite of the fact that it has been carefully flown by AEC and prospected on the ground by numerous private parties.

The Black Hills constitute an isolated dome surrounded by the relatively flat-lying sediments of the Great Plains, see Fig. 3. The dome is elongated to the south and northwest, has steep slopes on the sides, is nearly flat on top, and is subordinately fluted to a minor extent. It is about 125 miles long and 60 miles wide, its major axis extending from near the southwest corner of South Dakota to near the northeast corner of Wyoming. The central core of the dome is composed of pre-Cambrian igneous and metamorphic rocks which are exposed where the overlying sediments have been stripped away.

Stratigraphy

Sedimentary rocks from the Cambrian Deadwood formation through the upper Cretaceous Benton group are involved in the Black Hills uplift. These rocks represent approximately 4000 ft of sediments accumulated over the pre-Cambrian basement.

Although all the commercial ore in the Black Hills has come from the lower Cretaceous Inyan Kara group, uranium mineralization has been noted in several other units. Uranium has been found in association with thorium in the basal Deadwood conglomerate. Uranium, and weak to moderate radioactivity, has been noted in the Minnelusa black shales near Hot Springs, and several localities of anomalous radioactivity have been noted elsewhere in the Minnelusa and in the Sundance and Spearfish formations.

The Inyan Kara group comprises, in ascending order, the Lakota, Fuson, and Fall River formations. (The Fall River of the Black Hills is approximately equivalent to the Dakota of nearby areas and the names are loosely used synonymously). A thin limestone unit known as the Minnewaste is locally present between the Lakota and Fuson formations.

The group is characterized by alternating sandstone, siltstone, and mudstone, typically lenticular in section. The sandstones are commonly brown, buff, or gray and the mudstones are characteristically gray. Black shales, carbonaceous trash, and arkosic pebble conglomerates are common. Except for color, the group presents an appearance similar to the Salt Wash of the Colorado Plateau. The Inyan Kara group is overlain by the upper Cretaceous black shales of the Graneros formation. It is underlain by the Jurassic Morrison formation which is characterized in the Black Hills by greenish-gray shale with few limestone lenses and nodules, and less than 5 pct sandstone. The extremely fine grain, and resulting impermeability of the Morrison, render it one of the less favorable formations of the area, although ore grade uraniferous dinosaur bones are not uncommon.

General Structure: The Black Hills uplift is not the simple dome it appears to be on casual observation. It is characterized by many minor tectonic structures, which give rise to the fluted character of the southern Hills, and by numerous laccolithic domes and tectonic features which create a complicated structural pattern in the northern Hills. (See contour map of Black Hills uplift area, Fig. 4.)

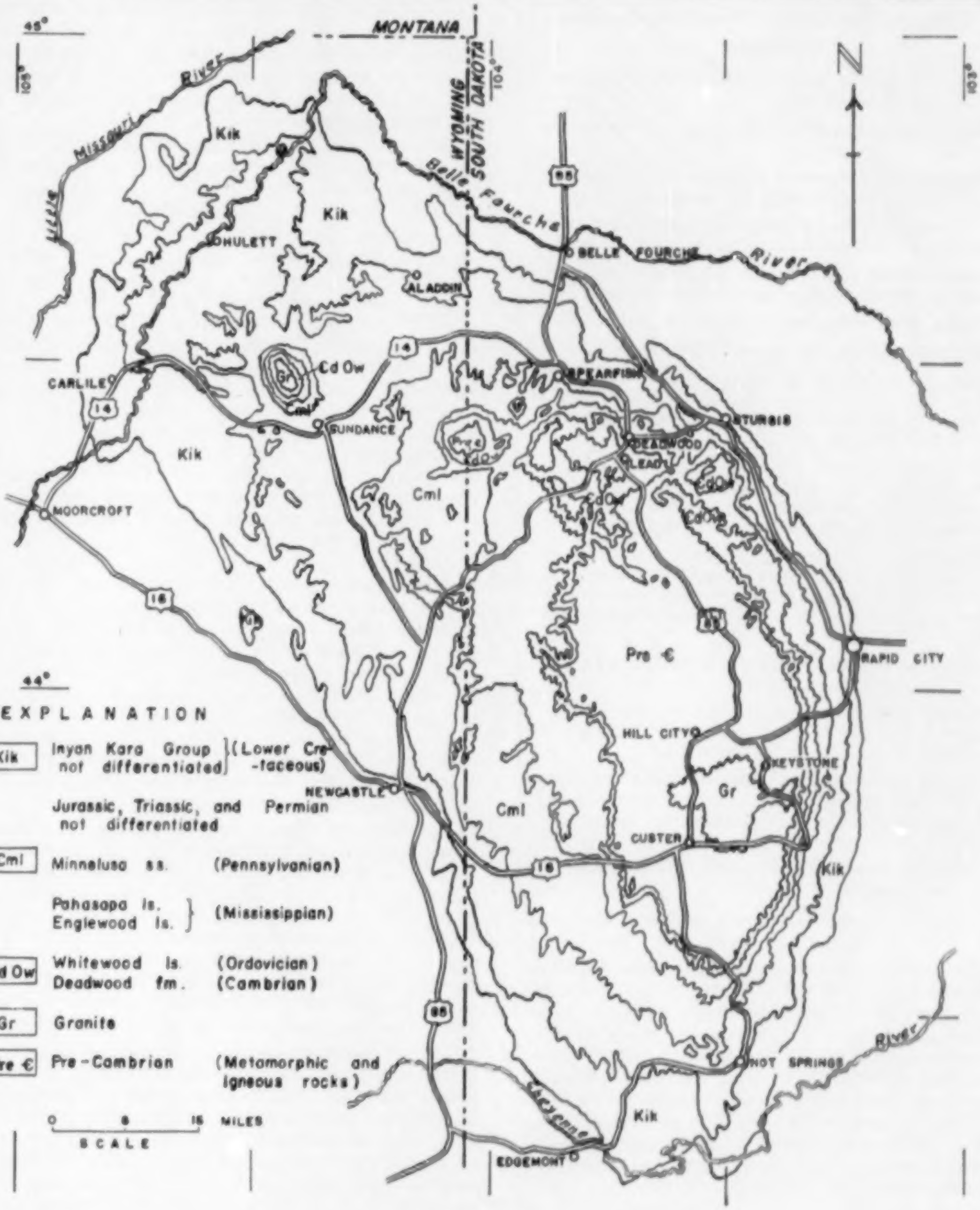
Between Hot Springs and Edgemont, S. D., are the Cascade anticline and the Chilson anticline with a broad intervening structural terrace. West of the Chilson anticline is another structural terrace which is broken sharply by a westerly dipping monocline. The Hartville uplift extends northward toward the Hills to break the hogbacks near Newcastle, Wyo., with some 3000 ft of vertical displacement. The Moorcroft anticline, lying along the western extremity of the Hills, bounds the large structural terrace east of Carlile, Wyo. The anticline plunging northwestward from the Bear Lodge Mountains is a broad prominent feature. Another strong anticline plunges northwestward from Sturgis, S. D., through Aladdin, Wyo. Several minor structures on the eastern flank of the Hills have, to date, received little detail study. Numerous prominent laccolithic-type domes, stocks, and plugs characterize the northern Black Hills. Of these, the Bear Lodge Mountains are the largest, with others, like Devils Tower and Bear Butte, providing outstanding landmarks. The rocks comprising these early Tertiary intrusions range in composition from monzonite to syenite. In addition to the prominent features there are scores of small domes which are probably also results of laccolithic type of intrusion. Some of the domes are characterized by very gentle dips, others by dips in the range of 15° to 20°. Their sizes run the gamut from the Bear Lodge Mountains to structures only a few hundred feet across. Some are cut by many faults, but faults are scarce or absent on most. While many of the domes exposing Fall River sandstone exhibit anomalous radioactivity, mineable ore has been found on only a few to date.

Ore Deposits

The uranium ore in the Black Hills occurs in bedded deposits in sedimentary rocks. Characteristic host rocks are thin-bedded, fine-grained, moderately friable quartz sandstones containing minor amounts of altered feldspar, devitrified volcanic ash, and carbonaceous material as accessories. Permeability of the host is typically moderate.

The ore deposits of the Black Hills are similar in some respects to those of the Colorado Plateau but differ markedly in other respects. Some of the more important characteristics of the Black Hills are shown in the box on page 44.

U. S. Geological Survey men working in the Black Hills noted some time ago that principal areas of uranium production coincide with major structural terraces of the Hills. Several anomalous areas and producing mines are located on the prominent terrace in the Edgemont district. The Carlile deposit



Generalized Geologic Map of the Black Hills Uplift Area

Fig. 3—The Black Hills constitute an isolated dome surrounded by the flat-lying sediments of the Great Plains (US AEC, Hot Springs, S. D. April 25, 1955).

Characteristics of the Black Hills Uranium Deposits

Size ranges from pods too small to mine to orebodies up to 50,000 tons.

Thickness ranges from less than 1 ft to nearly 20 ft.

Principal ore mineral is carnotite, although much tuyuyamunite is probably not recognized as such.

U:V ratio of the deposits is commonly 1:1.5, rarely, if ever, exceeding 1:5.

Lime content is commonly less than 1 pct with rare shipments containing more than 6 pct $CaCO_3$.

Copper is present only in trace amounts.

Asphaltic and **limestone** ores are unknown.

Logs are virtually nonexistent and twigs are rare, but carbonaceous sandstones and interbedded carbonaceous shales characterize the most favorable lithology.

Rolls, as known on the Plateau, are absent. The ore does not necessarily follow bedding, but departures are not abrupt and features like the crescentic rolls are unknown in the Hills.

Alteration of sandstone provides a good guide to favorability for a relatively small target area. A characteristic *purple-pink* ferruginous sandstone has been observed as a halo around many of the larger deposits.

Alteration of mudstone is not a recognized criterion. Red mudstones are rare in the Hills.

Jointing provides an important control for deposition and for the localization of high grade portions of the deposits of the Hills.

Channel control, as such, has not been observed in the Hills. Major channeling has recently been recognized, but possible relationship to ore deposition is not yet known.

Control by tectonic structures is believed to be of primary importance.

is on a broad structural terrace between the Moorcroft anticline and the Bear Lodge Mountains. Additional, less obvious examples might be cited. It was further noted that a coincidence exists between many anomalies and the flattening of dip on smaller structures superimposed upon the broad terraces. Some of the best orebodies are located on the structural flats immediately adjacent to an abrupt change in dip. Structural conditions are most favorable, therefore, on the margins of terraces, monoclines, anticlinal noses, and laccoliths.

To test the theory of structural control on the localization of ore deposition, the Commission committed approximately 4000 ft of diamond core drilling to an area that appeared particularly favorable. The project site, in East Red Canyon, lies along the western margin of structural terrace approximately four miles wide. It is immediately adjacent to a monoclinal fold dipping 15° to the west. One of the important mines of the district, the Holdup 15, lies about a mile to the north in the same position structurally. Surface geologic mapping indicates that a small nose or terrace exists on the monocline in the specific area considered. Drillholes were located along the monoclinal crest, both on the terrace side and on the dip side. Drilling was accomplished with 24 holes in an area approximately 2000 by 600 ft.

This project resulted in the discovery of an orebody of substantial size in a location where no surface exposures or anomalies exist. Subsurface maps indicate that, in addition to the structural favorability observed at the surface, a notable thinning of the ore-bearing sandstone occurs immediately updip from the orebody.

Description of three of the larger deposits will exemplify and amplify some of the associations and habits of ore which have been touched upon.

Carlile: The first important uranium discovery in the northern Black Hills, the Carlile deposit, stimulated much additional work by private industry and by the Commission. Investigation of an airborne anomaly, discovered by the Homestake Mining Co., disclosed visible carnotite on the tip of a small promontory of upper Lakota sandstone above the Belle Fourche River. Exploration of the promontory by wagon drilling indicated mineable tonnage of ore-grade material under relatively thin overburden. Additional surveys in the immediate vicinity disclosed a second important anomaly down the slope at the stratigraphic horizon of the Morrison formation. Investigation showed that the second anomaly represented a large landslide block, broken away from the promontory portion of the orebody and slumped down the canyon side over the plastic Morrison shales. The slump block was tilted during movement so that it dips steeply toward the direction from whence it came. As would be expected in a block nearly a quarter of a mile long, the slump area is characterized by a series of broken segments and steps which complicated the mining problem. This block was profitably mined by the open pit method with a stripping ratio of approximately 40:1. Mining of the promontory orebody was a simple stripping operation where only a few feet of cover existed on a flat-lying deposit.

Although the Carlile area is located on a broad structural terrace, insufficient data are at hand to state whether or not minor local structure plays an important role in ore deposition. The ore minerals commonly favor the joint surfaces and ore is usually higher in grade where joints are closely spaced. The top of the mudstone unit underlying the ore is marked by an uneven surface of swells and swales in the range of 10 to 20 ft in diam and less than 1 ft deep. Ore was observed to be richer in swale areas.

The ore-bearing sandstone unit, which is 15 to 20 ft below the top of the Lakota formation, is fine to medium grained, locally cross-bedded or laminated, buff to light gray in color, poorly cemented and friable. This sandstone is composed predominantly of subangular to subrounded quartz grains with some carbon trash, which is locally present in seams or strata up to 4 in. thick. Accessory minerals comprise moderate amounts of kaolinized feldspar, sparse ferromagnesian minerals, and muscovite flakes. Depositional environment of the ore-bearing sandstone was evidently that of abundantly loaded streams of moderate velocity whose courses were constantly changing, leaving interstream areas of quiet water deposition. Limonite staining is common and gypsum veinlets, commonly with radiating selenite crystals, are observed on some joints.

The principal ore mineral is carnotite, which is disseminated generally throughout the sandstone as a grain coating and interstitial filling. Ore minerals are commonly concentrated along crossbeds and in association with carbon flecks and galls. Other ore minerals identified at Carlile that are present in

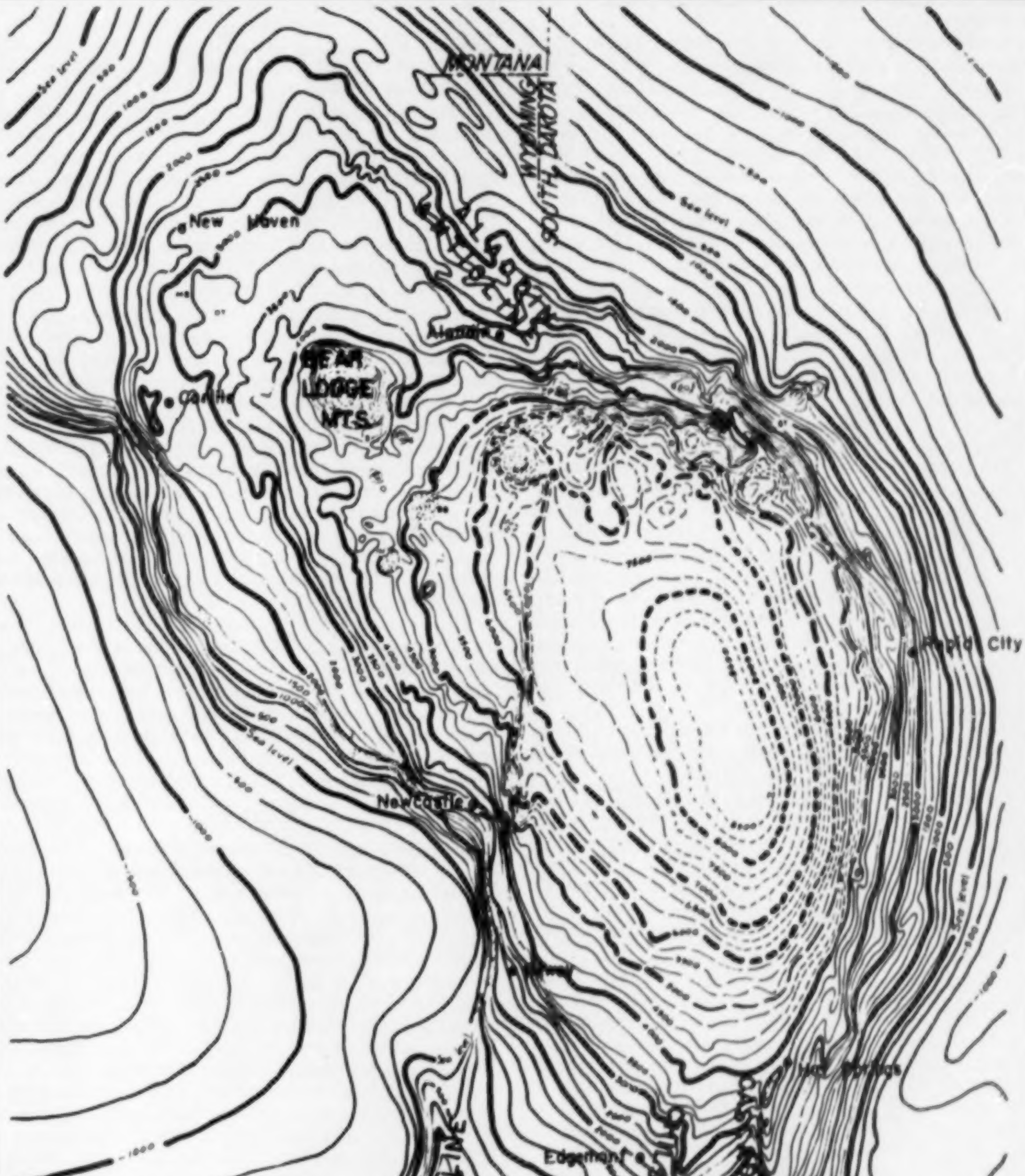


Fig. 4—Structure contour map of Black Hills uplift area, contoured at top of Minnekahta limestone. (After Darton, USGS Folio No. 108. April 22, 1955).

small to trace amounts are rauvite, coffinite, and doloresite. Additionally, hewettite, in radiating crystals, is found locally in the slump block. Uranium to vanadium ratio is about 1:1.5.

Recent drilling by the Commission on Thorn Ridge, near the Carlile mine, has disclosed that the ore there is associated with a flattened dip on a gently dipping surface. Although the evidence is inconclusive and drilling is still in progress, it appears that the subsurface structure contour map at the ore horizon is strikingly similar to that at the Virginia C mine in the southern Hills. In both cases, the uniform gentle dip of the terrace is broken by a flattened area several tens of acres in extent.

Virginia C: The Virginia C, first large producing orebody of the Edgemont district, was discovered by airborne reconnaissance. Subsequent exploration by wagon drilling indicated a substantial deposit overlain by a maximum of 40 ft of overburden. Early attempts to strip the deposit proved difficult and too costly, so underground methods were adopted.

The Virginia C is situated on a local flattening of regional dip in the southwest portion of the Black Hills dome. Subsurface structure contours, drawn on the basal sandstone of the Fall River formation, indicate a rather uniform dip of the sediments in the area with the uniformity broken by a terrace-like flattening in the immediate vicinity of the deposit. The mine is on the upthrown side of a major fault whose trace is less than 1000 ft southwest of the portal, and a minor fault with parallel trend has been noted in the eastern portion of the open cut. The mine is characterized by dozens of parallel faults of an inch or less displacement. Many of the joints and fractures have been filled with selenite which evidently is older than the ore.

The ore-bearing sandstone at the Virginia C lies approximately 25 ft above the base of the Fall River formation. The unit is composed of fine to very fine grained quartz sandstone, flat-bedded to cross-bedded, with local fine laminations of shaley material. Carbon flecks and seams are common. Calcareous cement is not abundant, the ore averaging 0.8 pct $CaCO_3$.

The principal ore mineral is carnotite, which appears to have been somewhat mobile since deposition. Rauvite and corvusite occur in appreciably smaller amounts. It was noted by Braddock that the carnotite and rauvite are associated in the lowest portion of the sandstone unit but that carnotite is seen only in the upper portion. Moreover, carnotite is observed to extend farther down-dip but not so far up-dip in relation to the corvusite-rauvite-carnotite portion. This mine is one of a group exhibiting relatively high vanadium content. Ore shipped from the Virginia C averages U:V::1:3. Many grab and channel samples are seriously out of equilibrium, but the average of lot samples of the ore shipped is close to equilibrium.

Gould Lease: The Gould Lease, in the Edgemont district, is situated on the structural terrace west of the Chilson anticline. Details of local structure are confused by lithologic and lithofacies problems, which are presently under study.

The ore is believed to be contained in the basal Fall River sandstone, in a portion of a very large channel scoured deeply into the Fuson shale. The stratum overlying the orebody comprises a boulder conglomerate, wherein blocks up to 15 ft in diam, predominantly of light gray silstone, lie at all angles in a matrix of coarse buff-gray sandstone. The basal surface of this overlying bed is very uneven as a result of local scouring. Mine mapping, which is still in progress as the mine develops, indicates tentatively that a relationship exists between the deepest scours and the best grade of ore.

The ore-bearing stratum is composed of subrounded to subangular, coarse to very coarse grained, brown to red-brown quartz sandstone. Black or smokey quartz is abundant, and approximately 5 pct of the rock consists of altered feldspar grains and devitrified ash. Carbonaceous material is conspicuously rare in this mine. The ore-bearing sandstone varies from 10 to 20 ft in thickness.

The ore mineral is carnotite, which occurs abundantly as an interstitial filling. Limonite occurs in great abundance as a grain coating and interstitial filling. The rock is very poorly cemented and lime content is extremely low.

Jointing appears to provide a major control of ore deposition. Two joint sets, both nearly vertical, diverge in strike at an angle of approximately 45°. Neither set maintains consistent control nor is either very much stronger or more consistent than the other. Intense mineralization follows a joint, or series of closely spaced joints, for a short distance and may then be sealed off by the intersecting set. Thus, the high-grade ore tends to wedge locally at the intersections.

Exploratory drilling continues on the structural terrace around the Gould lease. Location of drill-holes on the basis of combined favorability of structural flats and resistivity highs is proceeding with considerable success. The mineralization of barrenness has been successfully predicted in all holes drilled to date on this project.

Conclusions

Success in East Red Canyon and the existence of ore in a structurally favorable area at the Gould Lease has led the Hot Springs Sub Office to a new approach to exploratory drilling. Surface mapping, with particular emphasis on minor structures, is the basic tool in this program.

This approach to the problem is really nothing new but rather a variation of ideas that have been under consideration for some time. The concept that lithofacies changes are important to the localization of uranium ore deposition has been long considered on the Colorado Plateau, and in many places the importance of this change has been demonstrated. It is felt that the change from a clean sandstone section to an impermeable mudstone section favors deposition, in part, by inhibiting the flow of ore-bearing solutions. Decrease in permeability is only one of many factors involved. If these conditions constitute favorable lithology then how can they be predicted? As yet prediction of lithologic favorability has not progressed to a point of workability. But search has yielded a feature which is available as a useful tool at the surface. The structures mapped are features which tend to inhibit circulation of subsurface waters and therefore to destroy the equilibrium of a chemical system. The fact that many of the deposits of the Black Hills are known to lie on structural flats increases considerably the probability of encountering ore if the lithology is also favorable. A few selected holes on a favorable structure, drilled through the full section of the generally favorable Inyan Kara, give a considerably increased probability of ore or mineralized ground.

Energy Transfer by Impact

by R. J. Charles and P. L. de Bruyn

THE transfer of kinetic energy of translation into other forms of energy by impact is a fundamental process in most crushing and grinding operations. During and after the impact process the original source energy may be accounted for in any of the following possible forms:

1) Kinetic energy of translation of both the impacted and impacting objects.

2) Kinetic energy of vibration of the components of the impact system.

3) Potential energy as strain energy of the components of the system or in the form of residual stresses.

4) Heat generated by internal friction during plastic deformation or during damping of elastic waves.

5) New surface energy of fractured materials.

At any instant during the impact process only the strain energy of the components of the system can contribute directly to the brittle fracture process. If fracture is the desired result, as in comminution, it would seem advantageous to choose or arrange the conditions of impact so that a maximum amount of the original kinetic energy could be converted to strain energy at some moment during a single impact. The present work deals with determination of these desirable conditions for a simple case of impact and application of the principles involved to general cases of impact.

Experimental Method: Longitudinal impact of a rod with a fixed end was chosen as the impact system for investigation. The rod was mounted horizontally and the fixed end was formed by butting one end of the rod against a rigidly mounted steel anvil. The rod, of pyrex glass, was 10 in. long by 1 in. diam with both ends rounded to a 6 in. radius. The rounded ends permitted reproducible impacts on the free end of the rod and assured a symmetrical fixed end. Pyrex was selected as the rod material because of the marked elastic properties of such glass and the similarity of fracture between pyrex and many materials encountered in crushing and grinding operations. The frequency of natural longitudinal oscillation of the rod was 10 kc, and thus simple electronic equipment could be used for observation of strain changes occurring in the rod at this frequency.

As shown in Fig. 1, impacts on the free end of the rod were obtained either by a pendulum device or by a spring-loaded gun. Relatively heavy hammers (100 to 600 g) of mild steel were used in the pendulum impacts, while fairly light projectiles (20 to 80 g) were fired from the spring-loaded gun.

One of the main objects of the experimental work was to obtain the strain-time history of the rod as a function of the mass and kinetic energy of the impacting hammers. For this purpose a technique involving wire resistance strain gages and a recording oscilloscope was employed. Five gages were applied at equidistant sections along the rod, and by means of a switching arrangement the strain-time history at any section, and for any impact, could be obtained in the form of an oscillograph with a time base. The equation relating strain and voltage change across a strain gage through which a constant current is flowing is as follows:

$$\epsilon = \Delta v / iRF \qquad [1]$$

ϵ = strain, Δv = voltage change, i = gage current, R = gage resistance, and F = gage factor (from manufacturer's data — SRA type, Baldwin Lima Corp.).

With the above equation an oscillograph depicting voltage change vs time on a single trace can be converted directly to a strain-time diagram if a calibration of the vertical response on the oscilloscope screen for specific voltage inputs is available. In the present case the calibration was obtained by photographing precisely known audio frequency voltages on the same oscillograph as that on which a voltage-time trace from a strain gage had been made. Synchronization of the beginning of the single trace with the beginning of the impact was accomplished by permitting contact of the impacting objects to close an electrical circuit from which a voltage pulse, sufficient to initiate the trace, was obtained. The struck end of the rod was lightly silvered for purposes of electrical conduction so that it would form one of the electrical contacts. Markers every 100 micro-seconds on the traces served for a time base calibration.

Determinations of the kinetic energies of translation prior to impact were made in the case of the pendulum hammers by measuring the height of fall of the hammer and in the case of the projectiles by measuring the exit velocity from the gun barrel by means of an electrical circuit employing light sources, slits, and phototubes.[1]

During the experimental work it became evident that the time of contact between the impacting object and the rod was an important variable in the impact process. Measurements of the times of contact were made, therefore, for every impact for which a strain-time record was obtained. The time of contact was determined by permitting the impacting components, when in contact, to act as a closed switch and discharge a condenser at relatively constant voltage. The discharge was observed and photographed with a time base on the oscilloscope screen.

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Discussion of this paper, TP 4158B, may be sent (2 copies) to AIME before March 31, 1956. Manuscript, June 6, 1955. Abstracted from doctoral dissertation by R. J. Charles, Massachusetts Institute of Technology, 1954.

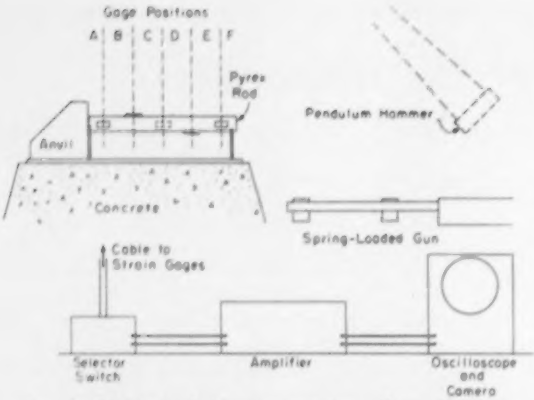


Fig. 1—Experimental impact apparatus. Heavy hammers (100 to 600 g) of mild steel were used in pendulum impacts and light projectiles (20 to 80 g) fired from the spring-loaded gun.

Fig. 2 illustrates a typical contact time trace and the electrical arrangement by which it was obtained.

Experimental Results

The immediate aim of the experiments was to determine the strains at various sections of the rod as a function of the impacting kinetic energies of the hammers, the Young's Moduli of the glass, and the durations of impact. Data for determination of all the above quantities were obtained in the form of oscillographs.

Interpretation of Oscillographs: The oscillographs from the impact tests showed voltage-time relationships which were obtained from the amplified signals of the strain gages. With the aid of the calibration signals included with each oscillograph and the strain gage equation, Eq. 1, any signal height on the traces could be converted to a strain value. The most important measurement taken from each voltage-time oscillograph was the voltage value at the instant when the bar had absorbed the greatest amount of strain energy during a particular impact. To locate this instant the following procedure was adopted.

From Hooke's Law the strain energy at a point in an object under simple compression or tension is proportional to the square of the strain at that point. An analysis of plots of the square of the strain at various gage sections of the impacted rod as a function of time showed that maximum strain energy absorption took place when the maximum elastic deformation developed at one section of the rod was greater than that developed anywhere else in the rod at any time during the impact process. Voltage measurements for the calculation of the maximum strain energy absorbed for a particular impact were made, therefore, on each set of five voltage-time traces at the time when maximum elastic deformation occurred; the latter condition was indicated by a maximum vertical response on one of the five voltage-time traces.

The experimental results showed that maximum strain was usually developed at either the struck or the fixed end of the rod but under certain conditions could occur at positions near the rod center.

From the large number of impacts on the pyrex rod the oscillographs shown in Figs. 3 and 4 have been selected as typical examples of the voltage-time traces obtained. The vertical dashed line in each of the figures indicates the time after the beginning of impact at which the strain values were measured. Traces marked X show the time of contact of the hammers and rods and traces marked Y are portions of the calibration signals. The solid vertical line near the center of the trace indicates the end of impact. The gage sections on the specimens, from which the signals were obtained, have been designated by two letters at the left of the figures which correspond to the gage positions as given in Fig. 1. All the traces show an initial period of loading of the rods during the impact and then a period after impact when the rod is left in a state of vibration.

Effect of Hammer Weight on Strain

Strain vs Time During Impact: In Fig. 3 the trace for Gage Section EF for the struck end of the rod shows two peaks during the time of impact. The occurrence of two peaks indicates that during the overall time of impact the rod received two separate blows, one following the other so rapidly that without sensitive methods of detection the impact would appear as one blow. The multiple blow effects were obtained when hammers weighing more than 200 g. were used for the impacts on the pyrex rod. Fig. 4 shows the corresponding trace obtained when the pyrex rod was impacted with a hammer weighing about 60 g. In this case the impact consists of a single blow of short duration which varies nearly sinusoidally with time for the duration of impact.

It will be shown that the time during which the impacting objects remain in contact is dependent on the mass of the hammer in such a manner that the heavier the hammer the longer the contact time. Mason[3] has shown that with contact times long compared to the period of fundamental oscillation of an impacted system the oscillations of the system modify the force developed at the point of contact in such a manner that it may consist of a series of blows. In this investigation, hammer weights 200 g and greater gave rise to impact times longer than the period of fundamental oscillation of the rod, and the forces developed at the struck end of the rod by these hammers showed more than one peak value

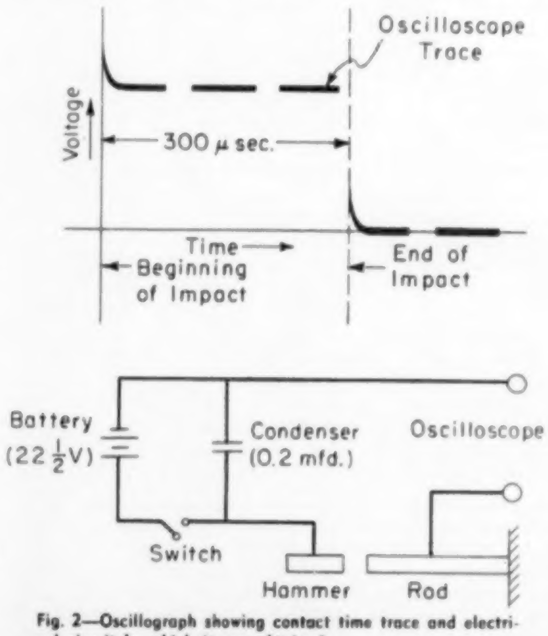
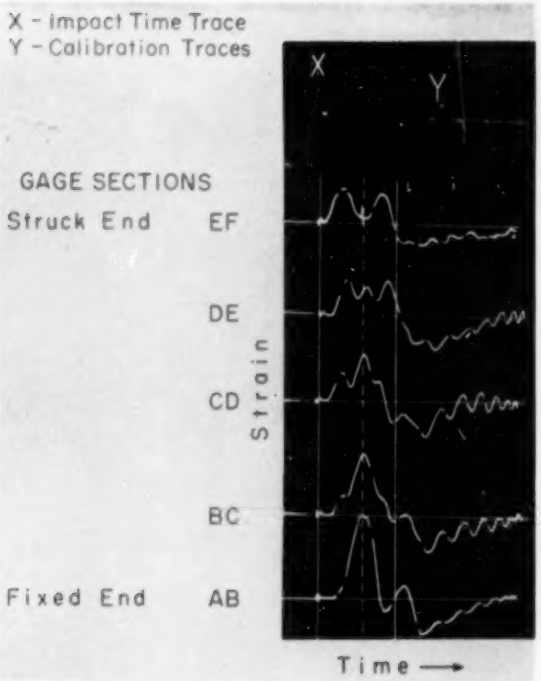
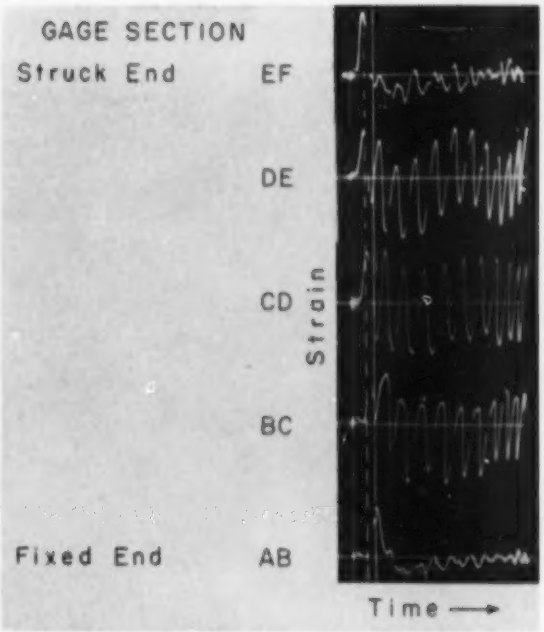


Fig. 2—Oscillograph showing contact time trace and electrical circuit by which it was obtained.





Figs. 3 and 4—Strain time traces (left) for impacts on pyrex rod with 593 g hammer and (right) with 59.3 g hammer.

during the time of contact. On the other hand, the times of contact for impact hammers weighing less than 100 g are shown, in the next section, to be less than the period of fundamental oscillation of the rod. In these cases the rod oscillations were not excited soon enough to modify the contact forces to any great extent and the traces for the struck end of the rod showed only one symmetrical peak during the time of contact.

A qualitative explanation of the effect of contact force on the rebound of the hammers from the struck end of the rod for impacts of the type illustrated in Fig. 3 may be given as follows: After the beginning of impact the contact force between the two objects increases to a maximum and then decreases almost to zero as the hammer decelerates to zero velocity and loses all its kinetic energy of translation. The hammer remains at rest for a short period of time until the rod, in extension, accelerates it in an opposite direction and thus causes rebound. The force causing rebound of the hammer is illustrated by the second peak on the strain-time diagram. When this force falls to zero, as given by the trace crossing, the abscissa of the strain-time diagram, the impact ends and the impacting objects separate. When a single strain peak is evident at the struck end of the rod during the time of contact, as illustrated in Fig. 4, the hammer is at rest when the contact force is a maximum and rebound is caused when this force decreases from a maximum to zero. Again, when the trace for the struck end first falls to zero the impact ends and the hammer continues in rebound.

In Fig. 3 the trace for gage section *AB* indicates the strain conditions near the fixed end of the bar. In this trace a single strain peak occurs considerably after the beginning of impact. The peak height shows that the strain at this instant at the fixed end of the rod is much larger than at any other section of the rod during the impact. At the same instant the strain reaches a maximum at the fixed end the strains at successive gage sections in the direction of the struck end become progressively smaller until at the struck end the strain is very nearly zero. In Fig. 4, however, maximum strain occurs at the struck end of the bar, and at this instant the strains at successive gage sections towards the fixed end decrease in intensity.

Most of the impacts investigated showed that if the loading pulse consisted of two strain peaks the maximum strain was developed at the fixed end of the rod and if the loading pulse consisted of a single strain peak the maximum strain was developed at the struck end of the rod.

Strain vs Time After Impact: An interesting effect can be observed in the strain-time records in regard to the amplitude of vibration of the rod after the impact has been completed. When the hammer rebounds after impact the rod continues to oscillate and, since both ends of the rod are free, the oscillation is essentially a harmonic vibration at the fundamental frequency of the rod. Under longitudinal harmonic oscillation all points of the rod pass through their equilibrium positions at the same instant and thus the signals from the various strain gages are in phase. The greatest strain is developed at the center of the rod and if the amplitudes of these strain signals (gages *CD*) are compared, it is noted that for short impact times the maximum amplitudes during free vibration are almost equal to the maximum peak amplitude during impact, Fig. 4, whereas for long impact times with heavy hammers, Fig. 3, the maximum amplitude during free vibration is much less than that during the impact. It would appear that heavy hammers, in rebounding, extract a much greater proportion of the strain energy and kinetic energy of vibration from the rods than do the light hammers where the impact times are relatively short. No experimental measurements were made of rebound velocities in this investigation, since the conditions of the impact system after the completion of impact were only of

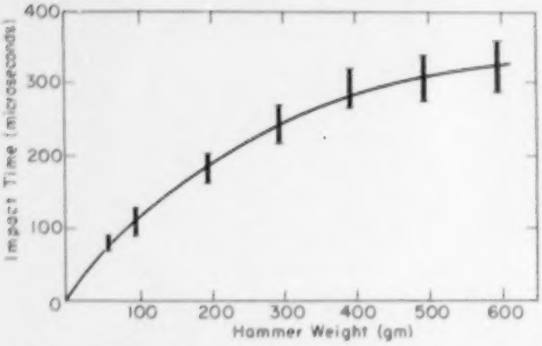


Fig. 5—Impact time vs hammer weight for impacts on a 10x1-in. pyrex glass rod.

passing interest and gave no information as to the conditions of impact during the impact time.

Effect of Hammer Weight on Time of Impact: Fig. 5 shows the experimental relationship obtained between the measured contact times of the hammers and rod and the weights of the hammers used in the impacts. Each of the solid vertical lines in these figures indicates the variation of the measured values for the impact times of any single hammer weight. Since the relative variation of the measured values of impact times increased with hammer weight the data are presented as varying over ranges rather than as single points representing averages of the experimental measurements.

Some of the experimental data from which the above figure was prepared indicate that the kinetic energy of impact may be a factor in determining the impact time for any single impact. The relatively large errors inherent in the method of measuring impact times, however, prevented a quantitative determination of this effect. A continuous curve, therefore, has been drawn through the vertical lines in the above figure.

Determination of the Young's Modulus of the Pyrex Glass: To calculate stress and strain energy values for the impact loaded rods several measurements were made of the Young's Modulus of the pyrex glass used in the experiments. It can be shown,[4] as in Eq. 2, that the longitudinal sound velocity in a solid is dependent only on the Young's Modulus and the density of the solid.

$$c = (Eg/\rho)^{1/2} \qquad [2]$$

where c = longitudinal sound velocity, E = Young's Modulus, g = acceleration of gravity, and ρ = density.

The fundamental time of longitudinal oscillation of the rod therefore would be dependent on these two characteristics and the dimensions of the rod. The Young's Modulus of the pyrex glass was obtained, therefore, from the following equation, Eq. 3:

$$E = \frac{4\,l^2 \rho}{T^2 g} \qquad [3]$$

E = Young's Modulus, l = rod length, ρ = density, T = period of fundamental oscillation, and g = acceleration of gravity.

The time of oscillation, T, was determined by examining the free vibration portion of the strain-time traces obtained by impacting the rod. The time taken for eight complete oscillations of the rod was measured and an average period of 93.7 microseconds calculated. The density of the rod was 2.31 g per cu cm, the length 25.4 cm, and the calculated Young's Modulus 6.93×10^8 g per cm.

Strain as a Function of Kinetic Energy of Impact at Constant Hammer Weight: The impact tests with any specific hammer weight showed that at the instant when the rod had absorbed a maximum amount of strain energy the squares of the strains at any of the bar sections were proportional to the impacting energy. Fig. 6, in which the square of the strains at various rod sections are plotted against the kinetic energies of impact, shows the above linear relationship for impacts of hammers weighing 593 and 59.3 g on the pyrex rod. The above graphs have been selected as representative of results obtained with any of the hammers or projectiles used in the investigation.

Discussion of Results

The experimental results from this investigation provide data for analysis of the loading forces which are derived from impact on a glass rod and for calculation of the maximum amounts of energy which are transformed from kinetic energy of impact to strain energy of the rod during impact. The data are also used to illustrate the effect of the mass of the impacting weight and the time of impact on the energy transfer process during impact.

Determination of Transfer of Kinetic Energy of Impact to Strain Energy: In the impact process when the hammer is decelerated to zero velocity all

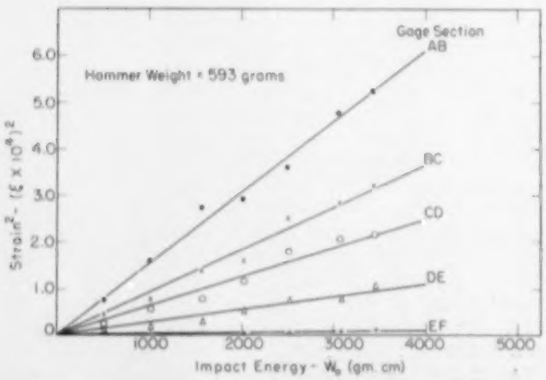


Fig. 6a—Impact energy vs square of strain at various gage sections of the pyrex rod for impacts with 593 g hammer.

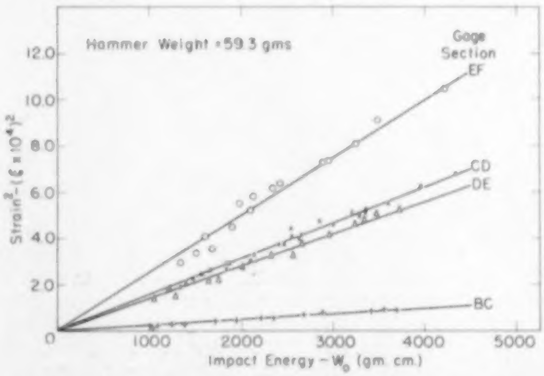


Fig. 6b—Impact energy vs square of strain at various gage sections of the pyrex rod for impacts with 59.3 g hammer.

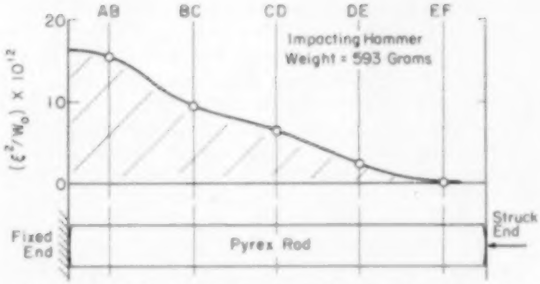
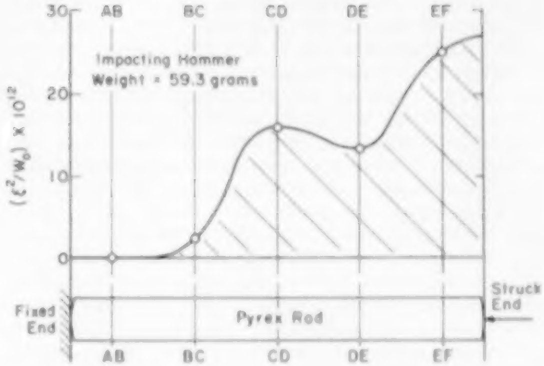


Fig. 7a (above)—Distribution of strain energy in impacted pyrex rod as a function of kinetic energy of impact. Fig. 7b (right)—Distribution of strain energy in impacted pyrex rod as a function of kinetic energy of impact.



its original energy of translation has been changed to other forms and the strain or potential energy of the hammer and rod system is at or near maximum. As the impact continues, the strain and vibrational energy of the system is partially reconverted to kinetic energy of translation of the hammer and rebound occurs.

The only form of energy that is *directly* usable in a comminuting or fracturing process *is the strain energy that has been momentarily stored in the rod and the hammer.* The experimental data of this investigation permit calculation of the maximum amount of strain energy absorbed by the rod. This maximum strain energy can be expressed as a fraction of the total kinetic energy of impact. The calculations are carried out as follows.

If the state of strain on a primatic bar is such that the strain at any cross-section is uniform but the strains at various cross-sections along the length of the bar are variable, then the total strain energy of the bar may be calculated as follows:

Let w_s = strain energy density (strain energy per unit length of rod), l = length of rod, and W_s = total strain energy of the rod. Then

$$W_s = \int_0^l w_s \, dl \qquad [4]$$

The strain energy density at any section is related to the strain at that section by the following equation, Eq. 5:

$$w_s = AE\epsilon^2/2 \qquad [5]$$

where A = cross-sectional area of the rod, E = Young's Modulus of the rod material, and ϵ = strain. Therefore,

$$W_s = (AE/2) \int_0^l \epsilon^2 \, dl \qquad [6]$$

When the strain conditions in the rod are brought about by longitudinal impact the amount of strain energy in the rod at any time may be expressed as a fraction of the kinetic energy of impact. Thus if the kinetic energy of impact is W_o, then

$$\frac{W_s}{W_o} = (AE/2) \int_0^l (\epsilon^2/W_o) \, dl \qquad [7]$$

The results from the strain measurements, as illustrated by the examples given in Fig. 6, showed a linear relationship between the kinetic energy of impact and the square of the strain produced at any gage section if the impacts were made with a specific hammer weight and if the strains were measured when the amount of strain energy absorbed was a maximum. The slopes of the lines in graphs such as are given in Fig. 6 correspond to the respective values of the term ϵ^2_{max}/W_o which appears in Eq. 7. The slopes provide a means of calculating the maximum fraction (W_s/W_o) of impact energy transferred to strain energy under various impact conditions.

For impacts with any single hammer, plots were made of the values of the term ϵ^2_{max}/W_o vs gage position on the rod and a smooth curve was drawn through the points. Fig. 7 illustrates two of these plots for impacting hammers weighing 593 and 59.3 g respectively. The graphs thus obtained showed the relative distribution of strain energy in the rod as a function of impact energy for the instant when the strain energy absorbed was a maximum. For impacts with any single hammer a value for W_s/W_o was calculated by graphically integrating the area under the appropriate strain distribution curve and multiplying by $AE/2$ as indicated by Eq. 6.

Table I. Maximum Fraction of Impact Energy Absorbed as Strain Energy for Impacts with Various Hammer Weights

Hammer Weight, Grams	Strain Energy Absorption Fraction
593	0.299
493	0.282
393	0.238
296	0.266
199	0.328
93.0	0.376
78.1	0.462
59.3	0.502
39.5	0.449
19.7	0.425

Table I lists the calculated values for the maximum amounts of impact energy transferred to strain energy within the pyrex rod for impacts with various weights of hammers.

Conditions Influencing Impact Times: The experimental results of impacts on pyrex rods given in a previous section indicate that the time of impact is primarily dependent on the mass of the impacting hammer and perhaps slightly dependent on the kinetic energy of impact. The Herzian theory of impact of spheres,[a] which may be applied to impact of rods with rounded ends, shows that the time of impact should be influenced primarily by the radii of contact and the masses of the objects. It also shows that the time of impact should vary inversely as the one-tenth power of the kinetic energy of impact. Therefore, although the impact time is slightly dependent on the kinetic energy of impact, the effect is almost negligible and the graph in Fig. 5, which shows time of impact as a function of the mass of the impacting hammer only, may be assumed correct for the correlation of impact time and absorbed strain energy.

Correlation of Impact Time and Strain Energy Absorbed: *Calculations from Experimental Results:* The experimental work of this investigation of impacts on pyrex rods furnished information for calculation of maximum strain energy absorption as a function of the impacting hammer weight. Times of impact were also measured as a function of impacting hammer weight and therefore a relationship between the maximum strain energy absorption and the times of impact can easily be obtained.

The curve marked *A* in Fig. 8 shows the variation of maximum strain energy absorption with the ratios of impact time to oscillation period for impact on the pyrex glass rod. In this figure the peak shows that there exists a time of impact of the rod for which the transfer of impact energy to strain energy is a maximum. The maximum amount of strain energy obtained within the glass rod is 0.5 times the kinetic energy of impact and is obtained from a loading pulse lasting about 75 microseconds. Examination of the strain-time traces shows that these particular loading pulses consisted of single blows. *Therefore, the main conclusion from the experimental work of this investigation is that a maximum transfer of kinetic energy of impact to strain energy is obtained when the impact time is a fractional part of the period of vibration of the impacted object and when the loading pulse consists of a single blow.* It may further be concluded that the time of impact and the character of the loading pulse are important factors if fracture of an object or failure of a structure is to be predicted.

Theoretical Calculations: Frankland[8] has given a theoretical analysis of impact in which force pulses of various shapes and durations are applied to a simple system consisting of an undeformable mass separated from a rigid reference plane by a spring. For purposes of calculation, only the fundamental mode of oscillation of the spring-mass system was considered operative in determining displacement of the mass as a function of time for various applied pulse loadings. From Frankland's results it is possible to calculate the relative amount of potential (strain) energy stored by the spring as a function of time for the various types of loading pulses applied to the mass. For any specific type of pulse and at some instant during the application of the pulse the amount of stored energy in the spring reaches a maximum value. For a specific vibrational system the relative value of the maximum stored energy is a function of the duration of the applied pulse. For the simple system of a reference plane, spring and mass, Fig. 9 shows the calculated relationship between the maximum energy stored in the spring and the duration of an applied load. The duration of the applied load is expressed as a fraction of the fundamental period of oscillation of the system and, also, as shown by the insert in Fig. 9, the applied load varies with time as the first half cycle of a sine wave.

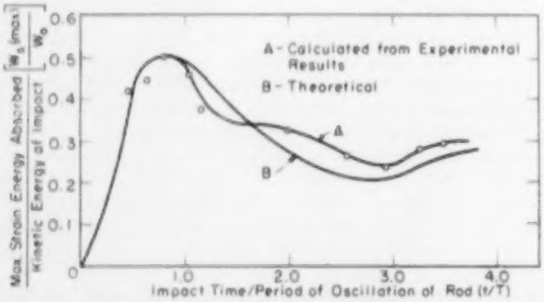


Fig. 8—Strain energy absorption coefficients vs impact time: period of oscillation ratios for impacts on pyrex rod.

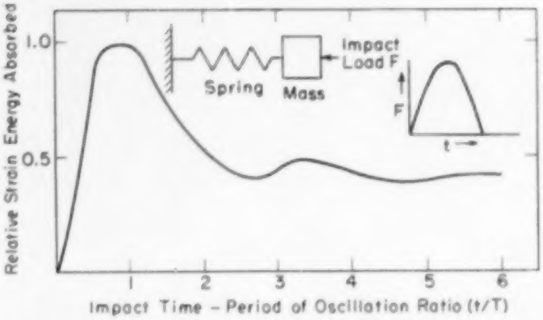


Fig. 9—Strain energy absorption vs impact time: period of oscillation ratio for impacts as simple spring-mass system. (After Frankland.)

The calculations permit only relative values for the absorbed strain energy; consequently the maximum of the curve in Fig. 9 has arbitrarily been assigned a value of unity.

It is clearly shown that maximum amount of strain energy absorbed by the hypothetical impact system is greatly dependent on the impact time and that there is a specific impact time for which maximum energy is absorbed as strain energy.

The curve in Fig. 9 has been redrawn as curve *B* in Fig. 8 and for purposes of comparison the ordinate value of unity in the theoretical curve has been made equal to the peak value for the fraction of impact energy observed as strain energy in the glass rod. For impacts on the glass rod the variation of the experimental strain energy absorption with the impact time-oscillation period ratios is very nearly that predicted by the theory developed by Frankland. Examination of the strain-time traces for the pyrex rods, however, shows that only in the case of impact hammers weighing less than 100 g do the impact pulses at the struck end of the rod assume a sinusoidal shape. For impacts with hammers weighing greater than 100 g a double peaked impact pulse was always obtained at the struck end of the rod. It may be observed, by examining Fig. 3, that the stress at the fixed end of the rod, however, varies nearly sinusoidally with time when double peaked impacting pulses are obtained at the struck end of the rod. Moreover, the time at which the strain values were determined was at the moment when the stress at the fixed end of the rod was at a maximum. Thus for the purposes of analysis the rod may be assumed to have been struck at the fixed end rather than at the end where hammer contact was made. Under these conditions, and since the assumed impact pulse at the fixed end has a nearly sinusoidal shape, the basic requirements for Frankland's theory have been fulfilled and a correlation between the theoretical and experimental results of the investigation should be expected.

Summary and Conclusions

The transfer of kinetic energy by impact to strain energy is a process that plays an important role in the comminution of brittle solids. Considered as a process, separate from the fracture process, the mechanism of energy transfer must be more fully understood before a complete analysis of size reduction can be realized. Studies of impact, which give information on energy transfer and stress conditions

arising from impact, have been made for the simple case of a rod fixed at one end and struck longitudinally at the other end with a moving object.

The information which was obtained in the experimental studies is summarized as follows:

1) The transfer of the kinetic energy of impact to strain energy of the rod is greatly dependent on the time during which the hammer and rod remain in contact. The experimental values of the impact times for which the energy transfer is a maximum for the pyrex rod is 0.8 times the period of fundamental oscillation of the rod and is in agreement with theoretical calculations. The maximum value of the ratio of strain energy absorbed to impact kinetic energy was 0.50 for the pyrex rod.

2) The impact times, which have been shown to be the controlling feature in the transfer of impact kinetic energy to strain energy of the rods, are determined mainly by the weight of the impacting hammers and the physical characteristics of the rods. Experimental results showed that for impacts on glass rods the time of impact decreased with decreasing hammer weight. Theoretical considerations indicate that the energy of impacts should have a small effect on the time of impact; the accuracy with which these measurements can be made, however, prevent any specific conclusions as to this effect.

3) Light-weight impacting hammers generated simple loading pulses, consisting of single blows, at the struck end of the pyrex rod. As the weight of the impacting hammer was increased the time of contact also increased so that the vibrational motions of the rods increasingly affected the shape of the loading pulse. With a maximum impacting weight of about 600 g on the 25.4 cm pyrex rod, the loading pulse consisted of two separate blows of almost equal intensity.

4) The maximum stress could be either at the fixed end or the struck end of the bar depending on the shape of the loading pulse. In general, when the loading pulse consisted of two well defined blows the maximum stress was developed at the fixed end of the rod and when the loading pulse consisted of a single blow the maximum stress was developed at the struck end of the rod.

5) The experimental results showed, qualitatively, that in the rebound of light hammers from the rod the amount of energy left in the rod as vibrational energy was much greater than in the case of rebound of relatively heavy hammers. Apparently the longer times of impact and the greater forces required for acceleration of the heavier masses in rebound caused a very significant damping action on the vibrations of the rods set up during impact.

From the experimental results as summarized above a number of general conclusions may be made as to the application of the impact studies to comminution. The most obvious conclusion is that if kinetic energy is to be most efficiently utilized in an impact process for size reduction, the time of impact should be as short as possible, for all practical purposes, and the intensity of impact as large as possible. The former condition assures a substantial transfer of kinetic energy to strain energy and the latter condition assures the development of stress values sufficient to initiate and propagate fractures.

Since the time of impact can be controlled only indirectly through adjustment of the masses and other physical characteristics of the impacting objects, short impact times can only be obtained by using impacting masses that are small compared to the impacted mass. The use of such impacting masses necessitates development of relatively high velocities of impact in order that sufficient amounts of energy are available for the size reduction process. Unfortunately, there are great mechanical difficulties in accelerating large numbers of particles to high velocities and the efficiency of developing high velocity impacts may more than offset the expected gain in efficiency of the size reduction process that makes use of these impacts.

From the experimental results it would appear that the use of small impacting masses at high velocities would have two other advantages in a size reduction process. The loading pulse would undoubtedly consist of a single blow of short duration and therefore it is more likely that the maximum stress would be developed at the point of contact rather than at the points which support the impacted mass. Thus the energy of impact would be transferred to strain energy within the impacted mass and the major portion localized near the point of impact for the short period of time necessary for fracture. In this manner only a small amount of energy would be passed through the impacted object and absorbed by the supports.

If the interpretation of the experimental results is correct in that light impacting hammers in rebounding cause only slight damping of the vibrations set up during impact then the use of small impacting masses in comminution may have another advantage. Rapid, successive impacts may have a cumulative effect on the internal vibrations set up in the impacted mass. It would be very unlikely that the internal vibrations would be neutralized by impacts occurring exactly out of phase with the preceding vibrations; therefore the most probable condition with successive impacts would be that the internal vibrations would increase in intensity. Thus fracture and size reduction may be accomplished by a succession of rapid, light blows of which any one taken singly would have no lasting effect on the impacted object.

Acknowledgments

The authors wish to acknowledge the invaluable assistance given them by their associates at the Massachusetts Institute of Technology and especially wish to thank A. M. Gaudin for his suggestions and constant interest in the investigation. This work was carried out under the Comminution Research Program of the Massachusetts Institute of Technology. Initial sponsorship of the Comminution Research Program was received from the Engineering Foundation. The current program is sponsored by the Engineering Foundation, the American Iron and Steel Institute, the U. S. Atomic Energy Commission, Aerofall Mills, Allis-Chalmers Mfg. Co., Bethlehem Steel Co., Kennecott Copper Corp., National Gypsum Co. and Union Carbide and Carbon Corp.

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Low-Temperature Carbonization of Lignite And Noncoking Coals in the Entrained State

Development work has shown that the yield of primary tar from coal is proportional to the heat in the volatile matter of the coal and that the yield of tar from noncoking coals may vary from 10 to 45 gal per ton on the ash-free and moisture-free basis. Pilot plant operations have proved that 100 to 135 pct of the bench-scale carbonization-assay yield of tar can be obtained.

by V. F. Parry, W. S. Landers, and E. O. Wagner

FOLLOWING investigations by the Denver Bureau of Mines on drying fine coal in the entrained state,[1,2] Texas Power & Light Co. employed the fluidized technique to upgrade Texas lignite for use in power plants. Because of the rapidly rising cost of natural gas in Texas the company agreed to cooperate with the Bureau of Mines in studying further the upgrading of lignite by low-temperature carbonization, since potential value of the tar would help offset the cost of fuel. Considerable interest was aroused, therefore, when Aluminum Co. of America decided to use dried lignite in its 240,000-kw power plant at Rockdale, Texas, operated by Texas Power & Light.

Carbonization of coal before burning in a power plant is not new. Plants in Germany have been operated for many years on carbonized brown coal and lignite briquets produced in large integrated plants. Large-scale experiments in carbonizing pulverized coal with hot flue gases were made 30 years ago at Milwaukee,[3] and many inventors have proposed other processes. In the U. S., technical and economic problems have prevented successful operation of large plants on carbonized coal, but new techniques of handling solids in fluidized beds may overcome these difficulties, particularly if the higher volatile noncoking coals are used.

Any bituminous material will decompose when heated to about 900°F to yield *primary* tar, gas, and char. The quantity of tar obtained from various coals depends on their rank and volatile content and to some extent on rate and method of heating. The liquid products derived from thermal decomposition of peat, brown coal, lignites, oil shale, and noncoking bituminous coals can be easily liberated by rapidly heating these materials in a fluidized bed at about 500°C (932°F). Since it takes only a few minutes to heat small particles of fuel to carbonizing temperature in a fluidized bed, processing plants can be built to handle up to 50 tph at relatively low cost. The pioneering development work being conducted at Rockdale, Texas, by Alcoa and Texas Power & Light will solve many engineering problems of such operations.

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Discussion of this paper, TP 4177F, may be sent (2 copies) to AIME before March 31, 1956. Manuscript, March 1, 1955. Chicago Meeting, February 1955.

The Bureau of Mines at Denver has studied the carbonizing properties of several hundred coals by small scale assay at 500°C, deriving a simple correlation between the potential yield of tar and the

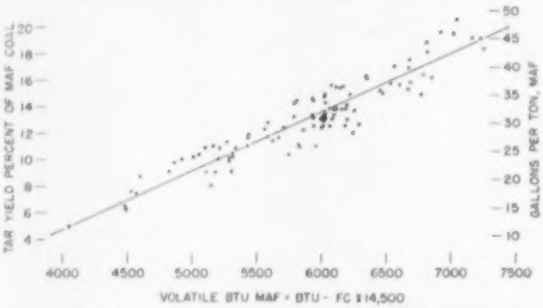

Fig. 1—Potential yield of primary tar from various coals.

proximate analysis. This correlation, shown in Fig. 1, compares the heat in the volatile matter of the coal with the potential yield of primary tar. The yield of primary tar varies from 12 to 50 gal per ton of pure coal.* About the same amount of heat is needed to

* *MAF* equals moisture-and-ash-free basis.

distil any dry coal at 500°C, and the time required to carbonize a given particle size is about the same for any coal. It is therefore obvious that coals rich in volatile matter will show the greatest profits when processed.

Texas lignites are rich in volatile matter, which contributes some 5700 Btu per lb of *MAF* coal, and the potential primary tar and oil yield from this lignite averages 12 pct by weight or 27 gal per ton from the pure lignite. Texas lignites are considerably richer in potential tar than lignites of North Dakota and Montana.

During 1950 the Bureau of Mines conducted many experiments on carbonizing fine dry coal in the entrained state, publishing a report[4] on major features of pilot and commercial-size units required to carry out the process. Additional experimental work has been done at Denver and the pilot plant has been improved, particularly the facilities for studying removal of fine dusts from tar vapors and gases at high temperatures by electrostatic precipitation. A number of materials have been carbonized, including sawdust, peat, brown coal, Brazilian oil shale, lignites, and the lower rank bituminous coals having noncoking properties. Straight coking coals cannot

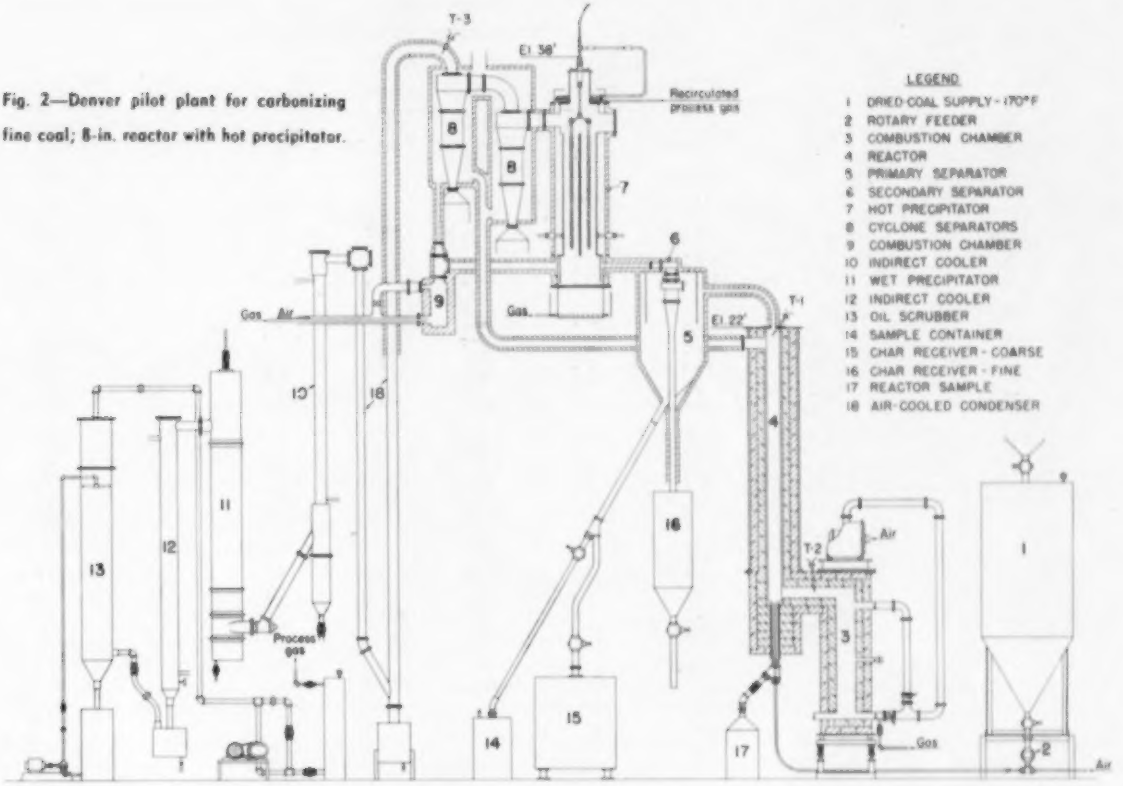

Fig. 2—Denver pilot plant for carbonizing fine coal; 8-in. reactor with hot precipitator.

be handled without severe preliminary oxidation to destroy the plastic property before carbonization. Dilute mixtures of coking coal and recycled char might be successfully carbonized by this technique.

It has been proved that results of pilot operations can be accurately projected to commercial-scale operation. By January 1953 enough information had been obtained from pilot-plant operations to warrant design of the full-scale commercial carbonizer now in operation at Rockdale.[5, 6] Specifications were approved in July, and the unit was constructed during the winter of 1953-54. The plant has been operated intermittently since March 1954 to refine the unit operations and to furnish char and tar for experimental purposes.

Table I presents carbonization data for seven representative coals ranging from a lignite with as-received heating value of 6500 Btu per lb through a high-volatile *B* bituminous coal with as-received heating value of 12,980 Btu per lb. Data are listed on the as-mined and moisture-and-ash-free bases, the as-mined analysis being estimated from various data available in Denver.

As part of the routine investigation, carbonization yields of any coals tested are quickly determined in the precision assay unit.[7] Small samples are carbonized in a fixed bed, and for comparative purposes the test is generally made at 500°C (932°F), the temperature giving maximum tar yield for most of the low-rank coals. Results of assay tests at 500°C on the seven coals considered here are shown in Table II. A special feature of this assay is the unusually good recovery of materials, ranging from 100.0 to 100.3 pct for the coals reported.

The pilot plant tests reported were made in the 8-in. diam fluidized-bed unit shown in Fig. 2. Basic elements of this carbonization unit have been described previously, but several improvements in materials collection have since been incorporated. The unit consists essentially of an externally heated retort (4) 8 in. ID and 13 ft long, fed continuously with a closely controlled mixture of fine dried coal and air. The usual charging rate is 360 lb of dried coal and 1080 std cu ft of air per hr. Coal is carried into the retort by the transport air and out by the volatile carbonization products and the products of

Table I. Index of Coals Tested in Laboratory Assay and Pilot Plant Units

				As-Mined*			MAF Analysis							
Name of Coal	Rank	State	County	H_2O, Pct	Ash, Pct	Btu per Lb	V.M.	F.C.	H_2	C	N_2	O_2	S	Btu per Lb
Garrison Dam	Lignite	N. Dakota	McLean	38.5	6.7	6500	47.4	52.6	4.7	70.8	1.2	22.6	0.7	11,870
Sandow	Lignite	Texas	Milam	35.6	9.3	7050	52.3	47.7	5.4	73.3	1.4	17.5	2.4	12,790
Pike View	Subc	Colorado	El Paso	26.6	4.8	8490	45.8	54.2	4.9	72.5	0.9	21.2	0.5	12,380
Elkol	Subb	Wyoming	Lincoln	23.5	2.0	9880	43.6	56.4	5.3	75.4	0.9	17.5	0.9	13,240
Danao	Subb	Philippines		18.0	3.6	10,540	43.0	57.0	5.4	74.8	1.9	17.5	0.4	13,450
Canon Chief	Suba	Colorado	Fremont	11.3	12.4	10,190	42.6	57.4	5.2	76.9	1.2	16.0	0.7	13,360
Kenilworth	Hvbb	Utah	Carbon	4.6	6.0	12,820	47.4	52.6	5.9	79.8	1.5	12.2	0.6	14,340

* Assumed as-mined analysis based on available Denver records.

Table II. Low-Temperature Distillation Assay Tests and Analyses

Name of Coal	Garrison	Sandow	Pike View	Elkol	Danao	Canon Chief	Kenilworth
Rank	Lignite	Lignite	Subc	Subb	Subb	Subs	Hvbb
Source	N. Dakota	Texas	Colorado	Wyoming	Philippines	Colorado	Utah
Temperature of distillation °C	560	500	500	500	500	500	543
Assay No.	374	413	359	377	380	370	428
Assay yield (MAF), pct:							
Char	68.5	65.8	69.4	71.0	72.2	74.7	67.5
Water formed	9.8	7.8	9.6	8.1	8.6	6.9	6.5
Tar, dry	5.5	11.9	8.0	11.6	10.2	10.5	16.6
Light oil	1.3	1.6	1.5	1.2	1.6	1.3	1.7
Gas	14.5	12.1	11.5	7.3	7.2	6.8	7.7
H_2S	0.5	1.1	0.2	0.7	0.2	0.1	0.3
Total	100.1	100.3	100.2	99.9	100.0	100.3	100.3
Composition of gas, pct:*							
CO_2	52.4	43.2	41.7	20.8	23.2	24.2	12.2
Illuminants	1.0	1.4	1.2	1.7	1.3	1.9	1.8
CO	12.6	12.6	15.7	18.0	13.1	14.3	10.4
H_2	10.3	12.6	13.5	12.9	15.9	12.6	19.4
CH_4	21.2	27.8	26.1	39.2	42.0	42.5	49.2
C_2H_6	2.5	2.4	1.8	7.4	4.5	4.5	7.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Net gas yield (MAF) cu ft per lb*	1.744	1.600	1.531	1.161	1.177	1.081	1.483
Heat in gas (MAF) Btu per lb	621	699	628	774	740	692	1127
Btu per cu ft calc., gross*	356	437	410	667	629	640	760
Specific gravity, 60°/30 in., dry, calc.	1.084	0.985	0.980	0.820	0.790	0.826	0.668
Proximate analysis of assay char (MAF), pct:	22.8	26.5	23.7	19.7	19.3	22.0	15.7
Volatile matter	77.2	73.5	76.3	80.3	80.7	78.0	84.3
Fixed carbon	14,010	13,870	13,940	14,210	14,240	13,990	14,650
Btu per lb							
Ultimate analysis of assay char (MAF), pct:							
Hydrogen	3.3	3.7	4.9	3.5	3.5	3.4	3.2
Carbon	85.1	83.8	72.5	85.5	85.0	85.3	89.1
Nitrogen	1.5	1.9	0.9	1.5	2.6	1.5	1.9
Oxygen	9.5	8.5	21.2	8.9	8.6	9.4	5.3
Sulfur	0.6	2.1	0.5	0.6	0.3	0.4	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Gas compositions and yields are computed on hydrogen sulphide, oxygen, and nitrogen free basis.

combustion of the transport air. Offtake temperature is controlled by regulating either external heat or coal input. About 40 pct of the heat of carbonization is supplied by heat transfer through the retort wall, and the remainder comes from internal combustion of the transport air in the bed. There is considerable evidence that the oxygen in the air combines with hot char recirculating internally throughout the bed without affecting the tar yield. All the products, including the char, tar, water vapor, and gas, leave overhead and enter the collecting system. The solids-recovery units consist of a primary separator, a high-efficiency cyclone (6) and electrostatic precipitator (7), and two medium-velocity cyclones (8) and (9). It is necessary to maintain this portion of the system above 750°F to prevent condensation of the tar. Any such condensate would come down with the solids and would bind or consolidate the dusts, preventing their easy removal, particularly in a continuous operation. Solids-collection data for several coals, showing the relative collection at the various points, are given in Table III. Efficient solids removal is necessary, since value of the tar recovered decreases with increasing solids content.

Table IV shows the yields obtained by carbonizing seven coals in the pilot plant. The *MAF* yield of tar varies from 2.9 pct for lignite from the Garrison Dam site in North Dakota to 20.6 pct for bituminous

Table IV. Yields of Products from Various Coals Carbonized in the 8-In. Fluidized Reactor

Name of Coal	Garrison Dam		Sandow		Pike View		Elkol	
Rank	Lignite		Lignite		Subc		Subb	
Source	North Dakota		Texas		Colorado		Wyoming	
Carbonizing temperature, °F	900		900		900		970	
Carbonization test No.	80		84		75		89	
Moisture in coal, as-mined, pct	38.5		35.6		26.6		23.5	
Ash in coal, as-mined, pct	6.7		9.3		4.8		2.0	
Basis	As-Mined	MAF	As-Mined	MAF	As-Mined	MAF	As-Mined	MAF
Air for transport, std. c.f. per lb	1.99	3.63	2.02	3.06	2.34	3.26	2.29	3.07
Yields, pct:*								
Char	45.2	70.2	46.9	71.8	53.3	70.7	50.4	65.0
Tar	1.6	2.9	6.0	10.8	4.7	6.8	11.1	14.9
Light oil	1.7	3.2	1.4	2.5	1.4	2.1	1.3	1.8
Gas	6.4	11.6	3.4	6.2	7.3	10.7	4.5	6.0
Water	43.3	8.8	39.2	6.6	32.8	9.1	30.4	9.2
Hydrogen and carbon gasified by transport air**	1.2	2.2	1.2	2.2	1.4	2.0	1.3	1.8
Unaccounted for	0.6	1.1	−0.1	−0.1	−0.9	−1.4	1.0	1.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Yields per ton:†								
Char, lb	904	1404	978	1436	1066	1414	1008	1300
Tar, gal	3	6	14	25	11	16	25	33
Light oil, gal	5.4	10	4.3	7.8	4.8	7.0	3.1	4.2
Gas, cu ft	5266	9770	4838	8780	6311	9200	6300	8460
Water, lb	866	176	784	132	656	182	608	184
Gas, Btu per lb of coal	416	772	325	589	528	769	727	976

* Yields shown represent yields of products obtained from the coal only. The transport air is not included.
** Based on assumption that 13.5 pct of the oxygen in the transport air forms H_2O and 86.5 pct forms CO_2.
† Gas and water figures include products of combustion resulting from transport air.

Table III. Distribution of Solids Collection in Pilot Plant Unit				
Name of Coal	Sandow	Pike View	Danae	Canon Chief
Carbonization test No.	84	75	88	76
Distribution of solids, pct of total:				
Primary separator	89.6	95.3	95.5	94.7
Buell separator	8.2	3.7	3.5	4.0
Hot electrostatic precipitator	1.3	0.3	0.7	0.8
First cyclone	0.4	0.2	0.0	0.1
Second cyclone	0.1	0.1	0.1	0.0
Total all collectors	99.6	99.6	99.8	99.6
Solids in tar	0.4	0.4	0.2	0.4
Total	100.0	100.0	100.0	100.0
Solids loading entering tar train grains per cu ft at temperature and pressure*				
Solids in dry tar, pct	2.48	2.95	0.91	2.93

* Expressed at temperature and pressure entering tar train.

coal from Kenilworth mine in Utah. On the as-mined basis, the tar-plus-light-oil yields range from 8.4 to 41.5 gal per ton. In each instance, heat in the product gas would be sufficient to carbonize the dried coal.

The chemical analyses of the raw and dried coals and the pilot-plant chars are given in Table V, which demonstrates the leveling-off effect of processing on the heating value of the solid fuel for boiler-plant use. For example, heating values of the raw fuels range from 6530 Btu per lb for Garrison lignite to 12,840 Btu for Kenilworth bituminous. With these differences individual firing schemes and boiler designs probably would be required to utilize the raw coals efficiently. Actually, an even greater difference exists on the net heat basis. On the other hand, heating values of the dried coals range from 9810 to 13,500 Btu per lb. Chars are even closer, with heating values of 10,730 to 13,220 Btu per lb.

The physical properties of the raw and processed coals handled in the pilot plant are shown in Table VI. As expected, the greatest degradation resulting from carbonizing occurs with the lowest rank fuels. Because the higher rank fuels contain less moisture, fewer cracks are opened as moisture is removed, and less degradation occurs. The low-packing densities for the Kenilworth char result from the incipient fusion and cenosphere formation the particles of this

Table IV. Continued

Danae		Canon Chief		Kenilworth	
Subb		Suba		Hvbb	
Philippines		Colorado		Utah	
930		900		1010	
88		76		98	
18.0		11.3		4.6	
3.6		12.4		6.0	
As-Mined	MAF	As-Mined	MAF	As-Mined	MAF
2.47	3.15	2.80	3.67	2.90	3.24
58.3	69.8	69.1	74.4	62.3	63.0
9.5	12.1	8.2	10.7	16.6	18.6
1.6	2.0	1.4	1.8	1.8	2.0
6.0	7.6	4.0	5.2	6.2	6.9
24.3	8.1	16.1	6.3	10.4	6.5
1.4	1.8	1.7	2.2	1.8	2.0
−1.1	−1.4	−0.5	−0.6	0.9	1.0
100.0	100.0	100.0	100.0	100.0	100.0
1166	1396	1382	1488	1246	1260
21	27	18	24	36	40
5.0	6.4	4.6	6.0	5.5	6.2
6640	8470	6880	9030	8250	9230
486	162	322	126	208	130
754	962	594	799	1304	1459

See footnotes on opposite page.

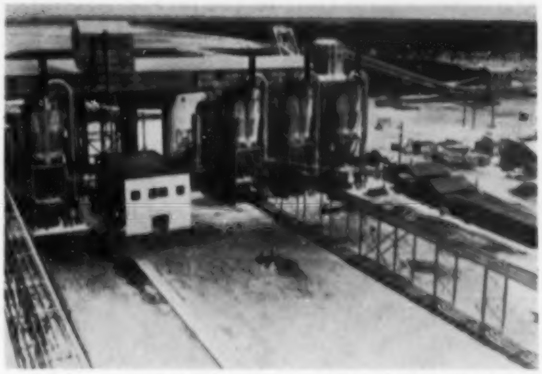

Fig. 3—Portion of the driers and lignite-handling facilities at Alcoa works, Rockdale, Texas.

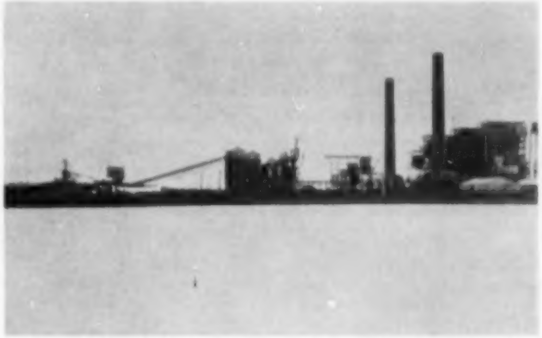

Fig. 4—View of lignite-handling and processing facilities and power plant at Alcoa works, Rockdale, Texas.

coal undergo during the extremely rapid heating in the retort.

Analyses of the gas produced during the carbonization runs are given in Table VII. The higher rank coals produce higher quality gases upon carbonization, but this is masked by the diluting effects of the products of combustion resulting from the air used to transport the coal into the retort. In each case resultant gases are rich enough to be burned easily with preheated air.

Table VIII gives properties of the primary tars obtained from the seven coals. These tars generally show a decrease in distillate yield with increasing rank of coal and a decreasing tar-acid content of the distillate. The neutral oil portion of the distillate increases and the aromatic content of the neutral oils decreases with the increasing rank of the parent coal.

Market studies and product research must be conducted to establish the value of low-temperature tars, since all are characterized by a high percentage of high-boiling fractions in the distillate, primarily in the tar-acid fraction. These tars are usually of low specific gravity (1.037 to 1.111) as compared to 1.2 sp gr for byproduct coke-oven tar.

It is interesting to compare, on an *MAF* basis, the yields of products obtained from the pilot plant with those from the small assay retort, see Table IX. Char is generally lower from the pilot plant because part of the char is consumed by combustion with air. The importance of distillation temperature is brought out by data on the Elkol and Kenilworth coals. In these cases the higher carbonizing temperatures reduce the char yield as compared to the yield

Table V. Chemical Analyses of Various Coals and Pilot Plant Chars*

Name of Coal	Garrison Dam			Sandow			Pike View		
Rank		Lignite			Lignite			Subc	
Source		North Dakota			Texas			Colorado	
Carbonization temperature, °F		900			900			900	
Carbonization test No.		80			84			75	
Condition	Raw	Dried**	Char	Raw	Dried**	Char	Raw	Dried**	Char
Proximate analysis, pct:									
H_2O	38.5	5.7	0	35.6	5.3	0	26.6	3.2	0
Volatile matter	25.7	39.1	22.4	28.4	41.8	29.1	32.4	41.1	25.2
Fixed carbon	29.1	43.5	62.2	26.7	39.2	51.9	36.2	48.9	65.2
Ash	6.7	11.7	15.4	9.3	13.7	19.0	4.8	6.8	9.6
Ultimate analysis, pct:									
H_2	6.9	4.5	2.9	7.0	5.0	3.2	6.3	4.7	3.0
C	38.9	58.4	69.2	40.3	59.4	63.9	49.3	65.1	74.0
N_2	0.6	1.0	1.3	0.8	1.1	1.4	0.6	0.9	1.0
O_2	46.5	23.8	10.6	41.4	19.0	10.6	38.7	22.0	11.9
S	0.4	0.6	0.6	1.2	1.8	1.9	0.3	0.5	0.5
Ash	6.7	11.7	15.4	9.3	13.7	19.0	4.8	6.8	9.6
Gross heat, Btu per lb	6530	9810	11,470	7160	10,520	10,730	8340	11,140	12,180
Fusibility of ash:†									
Ash-deforming temperature, °F	2130			2150			2310		
Ash-softening temperature, °F	2150			2180			2420		
Ash-fluid temperature, °F	2260			2210			2470		

* Analyses made by Coal Analysis section, U. S. Bureau of Mines, Pittsburgh, Pa. Pittsburgh moisture-free analyses corrected to Denver xylol moisture contents.

** Analysis of dried coal calculated from Pittsburgh moisture-free analysis of raw coal corrected to Denver xylol moisture content of dried coal.

† Repeated tests show no change in ash fusibility upon drying or carbonization.

Table VI. Physical Properties of Various Pilot Plant Samples of Raw, Dried, and Carbonized Coals

Name of Coal	Garrison Dam			Sandow			Pike View		
Rank		Lignite			Lignite			Subc	
Source		North Dakota			Texas			Colorado	
Carbonization temperature, °F		900			900			900	
Carbonization test No.		80			84			75	
Condition	Raw	Dried	Char	Raw	Dried	Char	Raw	Dried	Char
Size consist, cumulative pct retained:									
No. 4	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0
No. 8	42.3	1.9	0.4		0.8	0.2	29.7	12.4	3.3
No. 16	66.2	19.7	7.6		3.8	1.0	55.4	40.8	18.5
No. 30	79.5	51.8	34.0		15.7	8.8	73.4	66.1	44.7
No. 50	87.5	72.3	59.4		42.8	31.7	85.8	82.6	67.8
No. 100	92.7	77.7	68.6		54.6	46.8	92.3	89.2	78.9
No. 200	97.8	90.4	81.7		81.7	71.2	97.7	96.0	87.3
Pan	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0
Average size, in.	0.0822	0.0310	0.0210		0.0147	0.0105	0.0685	0.0500	0.0300
Rosin-Rammler "n"	0.89	1.06	0.92		0.92	0.94	0.90	1.08	0.96
Rosin-Rammler "$\bar{x}$", in.	0.116	0.029	0.019		0.013	0.009	0.079	0.050	0.028
Packing density, lb per c.f.:									
Loose	41.6	43.2	36.4		46.9	43.3	47.4	45.0	39.4
Compacted	50.3	52.1	42.6		53.8	49.6	53.5	51.7	45.8

Table VII. Analyses of Pilot Plant Carbonization Gases Obtained from Various Coals

Name of Coal	Garrison	Sandow	Pike View	Elkol	Danao	Canon Chief	Kenilworth
Rank	Lignite	Lignite	Subc	Subb	Subb	Suba	Hvbb
Source	N. Dakota	Texas	Colorado	Wyoming	Philippines	Colorado	Utah
Carbonization temperature, °F	900	900	900	970	930	900	1010
Carbonization test No.	80	84	75	89	88	76	96
Air per lb (MAF) coal, std. c.f.	3.63	3.66	3.26	3.07	3.15	3.67	3.24
Volume, pct:							
H_2S	0	0	0	0	0	0	0
CO_2	26.6	20.0	22.9	11.8	16.2	15.8	10.2
Illuminants	1.3	1.7	1.5	1.6	1.8	1.7	3.2
O_2	0	0	0	0	0	0	0
CO	2.5	3.7	5.5	10.1	6.1	5.5	6.2
H_2	2.9	2.8	3.5	6.6	5.0	2.2	8.6
CH_4	4.3	4.0	8.2	10.8	8.6	7.8	9.7
C_2H_6	3.8	2.0	1.2	1.8	3.6	1.9	6.7
N_2	58.6	65.8	57.2	57.3	58.7	65.1	55.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Specific gravity	1.084	1.053	1.042	0.940	0.991	1.015	0.926
Gross heat, Btu per c.f.	158	134	187	231	227	175	337

Table V. (Cont.) Chemical Analyses of Various Coals and Pilot Plant Chars*

Elkol			Danao			Canon Chief			Kenilworth		
Subb Wyoming 970 89			Subb Philippine Islands 930 88			Suba Colorado 900 76			Hvbb Utah 1010 98		
Raw	Dried**	Char	Raw	Dried**	Char	Raw	Dried**	Char	Raw	Dried**	Char
22.2	3.3	0	18.0	3.8	0	11.3	4.0	0	3.8	1.0	0
33.0	41.5	19.2	33.8	39.6	20.4	33.5	35.1	20.9	42.4	44.8	16.6
42.5	52.2	75.7	44.6	52.4	73.8	42.8	47.2	60.3	47.3	48.5	71.0
2.3	3.0	5.1	3.6	5.2	5.8	12.4	13.7	18.8	6.5	7.7	12.4
6.5	5.2	3.9	6.2	5.3	3.2	5.2	4.6	3.6	6.2	5.8	3.7
57.0	70.4	80.0	59.9	68.8	79.1	60.0	63.3	67.1	71.5	73.1	78.3
0.7	1.1	1.4	1.6	1.7	2.4	1.0	1.0	1.2	1.3	1.4	1.6
32.9	19.5	9.8	28.4	19.7	9.1	21.0	16.8	9.6	14.0	11.8	7.5
0.6	0.8	0.8	0.3	0.3	0.4	0.4	0.6	0.5	0.5	0.5	0.5
2.3	3.0	5.1	3.6	4.2	5.8	12.4	13.7	18.8	6.5	7.7	12.4
10,000	12,440	13,220	10,480	12,370	13,210	10,370	11,000	11,080	12,840	13,070	12,290
2840			2060			2330			2000		
2910 +			2080			2400			2100		
			2100			2580			2360		

See footnotes on opposite page.

Table VI. (Cont.) Physical Properties of Various Pilot Plant Samples of Raw, Dried, and Carbonized Coals

Elkol			Danao			Canon Chief			Kenilworth		
Subb Wyoming 970 89			Subb Philippines 930 88			Suba Colorado 900 76			Hvbb Utah 1010 98		
Raw	Dried	Char	Raw	Dried	Char	Raw	Dried	Char	Raw	Dried	Char
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
38.6	16.3	14.1	29.4	22.0	10.8	28.5	27.3	16.2	0.6	0.8	4.0
67.1	40.7	39.2	59.5	50.9	36.3	55.3	53.4	40.1	24.1	21.8	31.9
83.1	62.8	61.6	77.8	71.5	57.5	73.8	71.9	57.7	47.6	45.0	54.8
91.7	79.1	76.7	88.4	84.5	73.4	85.5	84.0	69.4	64.3	63.0	68.4
96.1	90.0	86.0	94.3	92.6	83.6	91.0	88.9	73.3	76.7	80.4	80.6
98.3	95.5	91.7	97.7	96.9	89.9	96.1	95.8	86.2	85.7	96.0	88.3
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.0810	0.0520	0.0490	0.0708	0.0612	0.0445	0.0675	0.0656	0.0485	0.0300	0.0290	0.0370
1.15	1.04	0.91	1.09	1.07	0.90	0.96	0.98	0.69	0.83	0.94	0.92
0.096	0.049	0.047	0.081	0.066	0.043	0.065	0.077	0.046	0.031	0.028	0.032
44.7	42.6	23.7	45.1	44.8	35.0	51.9	52.1	38.2	52.0	51.3	21.3
51.7	49.8	27.0	53.6	51.6	40.8	61.0	59.8	43.6	61.4	59.3	24.5

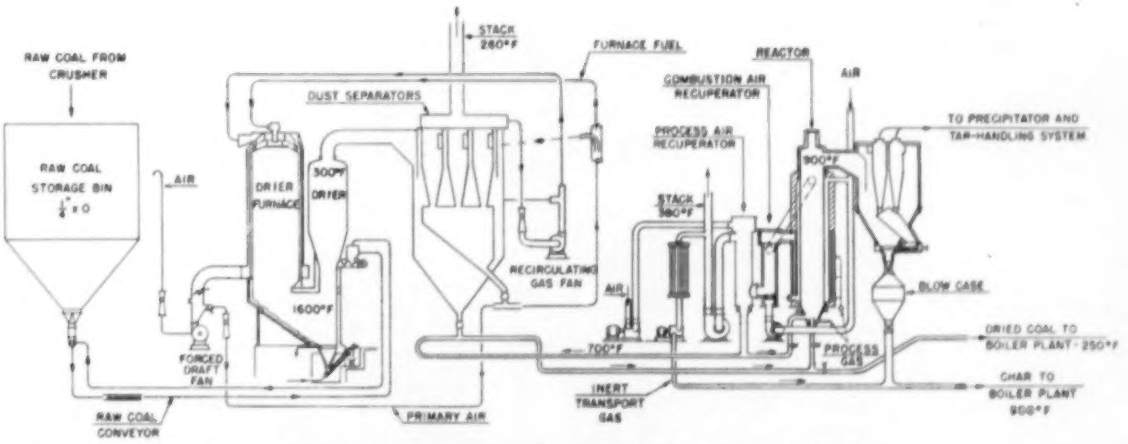

Fig. 5—Parry process for drying and carbonizing coal, U. S. Bureau of Mines, Denver.

Table VIII. Properties of Dry Primary Tar Obtained by Carbonization of Various Coals in Pilot Plant

Name of Coal	Garrison		Sandow		Pike View	
Carbonization test No.	80		84*		75	
Carbonization temperature, °F	900		900		900	
Specific gravity of crude tar, 20°/20°	1.070		1.037		1.037	
Benzene insoluble matter, pct	4.85		2.17		3.50	
Ash content of crude tar, pct	0.55		0.25		0.65	
Moisture in crude tar, pct†	25.8		5.2		8.8	
Distillation pressure, mm Hg abs	620		620		620	
Primary distillation yields, weight, pct						
Distillate	48.4		60.5		45.8	
Pitch	49.5		37.5		51.7	
Loss	2.1		2.0		2.5	
Temperature of decomposition, °C	312		322		304	
Specific gravity of distillate	0.986		0.964		0.948	
Yield of distillate, volume-pct	49.1		62.8		50.1	
Analysis of distillate (Hempel):	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.
To 170°C	5.7	0.837	3.3	0.810	4.5	0.822
170° to 200°C	3.4	0.940	5.2	0.895	9.0	0.920
200° to 210°C	5.5	0.976	4.4	0.920	5.9	0.933
210° to 235°C	15.4	0.982	12.4	0.938	13.1	0.938
235° to 270°C	15.1	0.990	17.0	0.964	22.0	0.942
270°-decomposition	48.2	1.005	52.4	0.974	40.0	0.954
Residue	5.9		4.2		5.1	
Loss	0.8		1.1		0.4	
Temperature distillate decomposition, °C	344		356		352	
Composition of distillate, volume-pct:						
Acids	48.7		30.5		31.3	
Bases	1.3		2.3		4.5	
Neutral oil	50.0		67.2		64.2	
Composition of neutral oil, volume-pct:						
Olefins	34.6		39.7		38.4	
Aromatics	40.9		35.6		36.7	
Paraffins	24.5		24.7		24.9	
Pitch residue:						
Melting point, cube-in-air, °C	135		191		142	
Specific gravity, 25°/25°	1.160		1.172		1.136	

* Tar data from test 81 (900°F).
** Blend of similar tests (89 and 90).
† As-received tar before dehydration-distillation.

from the assay. The yield of tar compares well, except for Elkol coal, where the pilot plant yield is 130 pct of assay yield. Yield of tar from pilot-plant operations is usually about that of the assay, but certain coals have shown yields considerably higher than assay, and it is believed that rate of distillation and, to some extent, temperature are responsible for the difference.

In designing the Alcoa plant at Rockdale, it was found necessary to establish the optimum operating temperature for Sandow lignite. This is defined as the temperature at which maximum tar yield is obtained, since it is assumed in considering this type of processing that the tar will have a higher value than the potential heat in the coal required to produce the tar. A series of four runs was made to establish the optimum operating temperature. Tables X through XIV present data for these runs, which were made at 900°, 950°, 1000°, 1100°F. Maximum yield of tar was obtained at 950° to 1000°F; however, since enough gas is produced at 950° to operate the carbonizer, it was tentatively decided that this temperature would be the most economical for plant operation. Temperatures slightly lower than 950°F may prove most economical when carbonizer capacity is the chief consideration. Distillate yield of the tars generally decreases with increasing temperature of carbonization, but within this range of temperature the gross chemical composition of the distillate does not appear to be much affected by the original temperature of carbonization.

Drying and Carbonizing Lignite at Rockdale, Texas

A general description has been published[3,4] of the plant and the lignite-processing facilities at Rockdale, with drawings showing the major features of

Table IX. Comparison of Yields of Products Obtained by Carbonization of Various Coals in the Pilot Plant and Precision Assay

Name of Coal	Garrison Dam		Sandow		Pike View		Elkol		Danao		Canon Chief		Kenilworth	
Rank	Lignite		Lignite		Subc		Subb		Subb		Suba		Hvbb	
Source	North Dakota		Texas		Colorado		Wyoming		Philippines		Colorado		Utah	
Carbonization unit	Pilot Plant	Assay	Plant Pilot	Assay	Pilot Plant	Assay	Pilot Plant	Assay	Pilot Plant	Assay	Pilot Plant	Assay	Pilot Plant	Assay
Carbonizing or assay test No.	80	374	84	413	75	359	89	377	88	380	76	370	98	428
Carbonization or assay temperature, °F	900	932	900	932	900	932	970	932	930	932	900	932	1010	1010
Yields, MAF pct:														
Char	70.2	68.5	71.8	65.8	70.7	69.4	65.0	71.0	69.8	72.2	74.4	74.7	63.0	67.8
Tar plus light oil	6.1	6.8	13.3	13.5	8.9	9.5	16.7	12.8	14.1	11.8	13.3	11.8	20.6	18.3
Water	8.8	9.8	6.6	7.8	9.1	9.6	9.2	8.1	8.1	8.6	6.3	6.9	6.5	6.5
Gas, Btu per lb MAF coal	772	621	589	699	769	628	976	774	962	740	798	692	1459	1127

Table VIII. (Cont.) Properties of Dry Primary Tar Obtained by Carbonization of Various Coals in Pilot Plant

Elkol		Danae		Canon Chief		Kenilworth	
89**		88		76		98	
970		930		900		1010	
1.076		1.079		1.084		1.111	
0.21		0.97		3.14		2.78	
0.06		0.05		0.49		0.40	
8.4		6.2		6.0		1.5	
620		620		620		620	
54.1		44.8		43.5		39.6	
45.2		54.6		54.6		59.0	
0.7		0.6		1.9		1.4	
305		304		310		308	
0.984		0.988		0.932		0.956	
55.0		48.9		46.7		46.0	
Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.
5.4	0.822	2.8	0.803	8.9	0.807	4.8	0.806
5.3	0.924	5.8	0.940	10.3	0.900	6.4	0.880
4.8	0.941	3.1	0.958	6.5	0.925	2.7	0.923
13.3	0.968	12.1	0.970	14.7	0.932	11.2	0.947
27.5	0.995	25.2	0.986	21.3	0.941	19.4	0.959
32.5	1.005	36.4	1.002	36.8	0.944	47.9	0.984
9.7		10.8		3.8		6.8	
1.5		1.8		0.7		0.8	
330		325		340		372	
46.6		47.9		33.8		30.4	
4.0		3.3		2.0		3.4	
49.4		48.8		64.2		66.2	
39.6		39.1		38.3		37.7	
27.8		28.6		31.8		34.9	
32.6		32.3		35.9		27.4	
192		155		182		202	
1.221		1.174		1.177		1.240	

See footnotes on opposite page.

design of the drying and carbonizing units. Lignite is mined about four miles from the boiler plant, crushed in the field to −6 in., and carried on a belt conveyor to the power plant area. Here it passes through hammer mills for reduction to −¼ in. and then moves on belt conveyors to large concrete storage silos serving the drying units. Nine drying units serve the three steam-generating units. Fig. 3 shows four drying units and part of the lignite-handling and storage facilities.

Fig. 4 is a picture of the power plant and lignite-processing facilities taken during the winter of 1953. Crushing and storage facilities are on the left and driers in the center. The steelwork for parts of the prototype carbonizer is shown between the drying units and the steam generators. A schematic design

Table X. Effect of Temperature on Yields from Sandow, Texas, Lignite Carbonized in the 8-In. Fluidized Reactor

Carbonization temperature, °F	900		950		1000		1100	
Carbonization test No.	84		92		82		83	
Moisture in co.., as-mined, pct	35.6		35.6		35.6		35.6	
Ash in coal, as-mined, pct	9.3		9.3		9.3		9.3	
Basis	As-Mined	MAF	As-Mined	MAF	As-Mined	MAF	As-Mined	MAF
Air for transport, std. c.f. per lb	2.02	3.66	2.00	3.63	2.07	3.76	1.99	3.62
Yields, pct*								
Char	48.9	71.8	46.4	67.4	44.9	64.6	42.7	60.6
Tar	6.0	10.8	6.6	11.9	6.5	11.8	5.6	10.1
Light oil	1.4	2.5	1.4	2.6	1.7	3.1	2.2	4.0
Gas	3.4	6.2	4.7	8.5	5.4	9.8	8.6	15.6
Water	39.2	6.6	39.6	7.2	40.2	8.4	40.3	8.6
Hydrogen and carbon gasified by transport air**	1.2	2.2	1.2	2.2	1.2	2.2	1.2	2.3
Unaccounted for	−0.1	−0.1	0.1	0.2	0.1	0.1	−0.6	−1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Yields per ton†								
Char, lb	978	1436	928	1348	898	1292	854	1212
Tar, gal	14	25	15	27	15	27	12	22
Light oil, gal	4.3	7.8	4.6	8.3	5.4	9.8	6.6	12.0
Gas, cu ft	4838	8780	5201	9440	5499	9960	6551	11,890
Water, lb	784	132	792	144	804	168	806	172
Gas, Btu per lb of coal	325	589	463	840	865	1007	920	1670

* Yields shown represent yields of products obtained from the coal only. The transport air is not included.
** Based on assumption that 13.5 pct of the oxygen in the transport air forms H_2O and 86.5 pct forms CO_2.
† Gas and water figures include products of combustion resulting from transport air.

Table XI. Chemical Analyses of Sandow, Texas, Lignite and Chars, Produced at Various Temperatures in Pilot Plant

Carbonizing temperature, °F			900	950	1000	1100
Carbonization test No.	All	All	84	92	82	83
Condition	Raw	Dried	Char	Char	Char	Char
Proximate analysis, pct:**						
H_2O	35.6	5.3	0	0	0	0
Volatile matter	28.4	41.8	29.1	25.4	25.2	22.0
Fixed carbon	26.7	39.2	51.9	54.0	54.8	56.9
Ash	9.3	13.7	19.0	20.8	20.0	21.1
Ultimate analysis, pct:						
H_2	7.0	5.0	3.2	3.0	2.8	2.5
C	40.3	59.4	63.9	63.3	65.4	65.6
N_2	0.8	1.1	1.4	1.4	1.4	1.4
O_2	41.4	19.0	10.6	9.9	8.7	7.7
S	1.2	1.8	1.9	1.8	1.7	1.7
Ash	9.3	13.7	19.0	20.6	20.0	21.1
Gross heat, Btu per lb	7156	10,520	10,730	10,640	10,740	10,860
Fusibility of ash:						
Ash-deforming temperature, °F	2150					
Ash-softening temperature, °F	2180					
Ash-fluid temperature, °F	2210					

* Analyses made by Coal Analysis Section, U. S. Bureau of Mines, Pittsburgh. Pittsburgh moisture-free analyses corrected to Denver xylol moisture contents.
** Analysis of dried coal calculated from Pittsburgh moisture-free analysis of raw coal corrected to Denver xylol moisture content of dried coal.

Table XII. Physical Properties of Sandow, Texas, Dried Lignite and Chars, Produced at Various Temperatures in Pilot Plant

Carbonizing temperature, °F	900		950		1000		1100	
Carbonization test No.	84		92		82		83	
Condition	Dried	Char	Dried	Char	Dried	Char	Dried	Char
Size consist, cumulative pct retained:								
No. 4	0	0	0	0	0	0	0	0
No. 8	0.8	0.2	0.6	0	0.4	0.1	0.8	0.2
No. 16	3.8	1.0	3.9	0.2	3.6	1.5	4.1	0.8
No. 30	15.7	8.8	19.3	8.0	18.7	9.7	19.0	7.8
No. 50	42.8	31.7	45.6	33.3	46.1	33.0	45.3	28.9
No. 100	54.6	46.8	68.0	59.0	55.7	39.7	60.6	40.7
No. 200	81.7	71.2	81.5	76.3	81.0	71.3	81.4	69.7
Pan	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Average size, in.	0.015	0.010	0.016	0.011	0.015	0.010	0.016	0.010
Rosin-Rammler "n"	0.92	0.94	1.00	1.11	1.00	0.94	0.96	0.94
Rosin-Rammler "$\bar{x}$", in.	0.013	0.009	0.013	0.010	0.013	0.010	0.013	0.008
Packing density, lb per c.f.:								
Loose	46.9	43.3	47.9	42.5	46.9	41.8	46.9	40.1
Compacted	53.8	49.6	54.9	49.2	54.2	47.2	54.6	45.9

of an integrated drier and carbonizer simulating the installation at Rockdale is shown in Fig. 5, which indicates the relative size of the units. Cyclone separators are not enclosed in the primary separator at the Rockdale plant.

Crushed lignite is moved from the storage bin by a mechanical conveyor which feeds a variable-speed screw leading to the drier column. Hot gas from combustion of fine dried-lignite dust collected in the final cyclones at the end of the drying unit enters the drying column at 1600° to 1800°F. The raw lignite is entrained in this gas and heated to drying temperature, and flow of materials is regulated to maintain temperatures of 300° to 350°F at the outlet of the drier column. Under these conditions, raw lignite containing about 36 pct moisture is thermally dried to a moisture content of 3 to 5 pct. The dried product is separated from the gases and moisture vapor in a primary separator, and fine dust is selectively separated from the gas stream to furnish the fuel necessary for operating the drier. Five to seven pct of the dried lignite is required to heat the drier.

Table XIII. Analyses of Gases Produced by Carbonization of Sandow, Texas, Lignite at Various Temperatures in Pilot Plant

Carbonization test No.	84	92	82	83
Carbonizing temperature, °F	900	950	1000	1100
Air per lb (MAF) coal, std. c.f.	3.66	3.63	3.76	3.62
Volume, pct:				
H_2S	Trace	0.2	Trace	0.1
CO_2	20.0	20.9	20.8	21.1
Illuminants	1.7	2.6	2.7	4.3
O_2	0.0	0.0	0.0	0.0
CO	3.7	3.8	4.1	4.6
H_2	2.8	3.8	3.2	10.0
CH_4	4.0	6.6	7.1	9.6
C_2H_6	2.0	1.5	2.6	2.3
N_2	65.8	60.6	59.5	48.0
Total	100.0	100.0	100.0	100.0
Specific gravity	1.053	1.038	1.042	0.976
Gross heat, Btu per c.f.	134	177	202	281

The dried product is moved from the primary separator to the boiler plant or to the carbonizer by pneumatic transport. Air is used as the conveying medium. When the dried lignite is carbonized, preheated air from a recuperator on the carbonizer picks up the lignite and transports it to the reactor. The quantity of air used ranges from 3 to 4 cu ft per lb of dry lignite, and the combustion of this air with the lignite char in the reactor furnishes about 70 pct of the heat required for carbonization. The balance of the heat is transferred through the walls of the externally heated reactor. The carbonizer is heated by combustion of process gas admitted at several ports in the lower half of the furnace. A mixture of air with products of combustion drawn from the stack is preheated in the combustion air recuperator and passes through several internal flues to the burner ports. The recirculated combus-

Table XIV. Properties of Dry Primary Tar Obtained by Carbonization of Sandow, Texas, Lignite at Various Temperatures in Pilot Plant

Carbonization test No.	84*		92		82		83	
Carbonization temperature, °F	900		950		1000		1100	
Specific gravity of crude tar, 20°/20°	1.037		1.041		1.055		1.074	
Benzene insoluble matter, pct	2.17		2.19		2.54		3.15	
Ash content of crude tar, pct	0.28		0.18		0.19		0.06	
Moisture in crude tar**	5.2		5.1		7.2		8.3	
Distillation pressure, mm Hg abs	620		620		620		620	
Primary distillation yields, weight-pct								
Distillate	60.5		59.8		47.0		47.7	
Pitch	37.5		38.5		52.0		51.3	
Loss	2.0		1.7		1.0		1.0	
Temperature of decomposition, °C	322		306		302		284	
Specific gravity of distillate	0.964		0.964		0.966		0.979	
Yield of distillate, volume-pct	62.8		64.6		48.7		48.8	
Analysis of distillate (Hempel):	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.	Weight, Pct	Sp. Gr.
To 170°C	3.3	0.810	4.5	0.819	5.1	0.834	6.7	0.830
170° to 200°C	5.2	0.895	6.1	0.910	7.7	0.912	9.9	0.915
200° to 210°C	4.4	0.920	5.1	0.924	5.6	0.932	7.9	0.938
210° to 235°C	12.4	0.938	11.9	0.944	14.4	0.946	13.4	0.957
235° to 270°C	17.0	0.964	18.4	0.965	22.1	0.962	22.4	0.986
270°C to decomposition	52.4	0.974	47.8	0.971	40.4	0.980	33.9	1.011
Residue	4.2		5.0		3.9		5.2	
Loss	1.1		1.2		0.8		0.6	
Temperature distillate, decomposition, °C	356		351		340		394	
Composition of distillate, volume-pct:								
Acids	30.5		32.8		33.2		37.4	
Bases	2.3		2.2		2.0		2.2	
Neutral oil	67.2		65.0		64.8		60.4	
Composition of neutral oil, volume-pct:								
Olefins	39.7		38.6		33.2		36.0	
Aromatics	35.6		36.8		40.4		38.4	
Paraffins	24.7		24.6		26.4		25.6	
Pitch residue:								
Melting point, cube-in-air, °C	191		196		198		209	
Specific gravity, 25°/25°	1.172		1.185		1.184		1.217	

* Tar data from test 81 (900°F).
** As-received tar before dehydration-distillation.

tion products prevent excessive furnace temperatures when the process gas is burned with minimum excess air, and variation of recirculated gas permits regulation of the flame over a substantial part of the furnace without local overheating. This system permits uniform heating of the reactor and high rates of heat transfer from flame to reactor wall by direct radiation from the burning gas.

The dried lignite is carried through the reactor by the gases formed by combustion of the air and by the gases and vapors formed by carbonization of the lignite. Flow of lignite is controlled to maintain a heat balance when the temperature of the mixture leaving the reactor is about 500°C (932°F), the optimum temperature required to produce maximum yield of tar. Most of the char resulting from carbonization is separated from the gases and vapors in the primary separators and cyclones. A small percentage of ultrafine dust passes on with the gases through an electrostatic precipitator and additional cyclones that remove a large part of the entrained material. The cleaned gases and vapors then pass into the tar-condensing train.

The tar-condensing train is a flexible unit designed for studying various schemes for condensing and handling the liquid and gaseous products. Various fractions of tar condensate can be handled, or the total crude product can be combined and pumped to storage or to tank cars.

The final char collected in the precipitator and final cyclones is moved to the primary separator, and the total product char is transported pneumatically with inert gas to the fuel-storage silo at the boiler plant. The inert gas used for this operation is taken from the stack of the carbonizer. At the boiler plant char is separated from inert gas by passage through a cyclone and is deposited in a large bin. Fuel lines lead from this bin to the burners. The steam generators are Combustion Engineering tangentially fired slagging-type units with a nominal rating of 640,000 lb of steam per hr.

Drier Operation to October 1954: The first group of three driers was placed in operation in December 1953, when the No. 1 boiler was completed, and by April 1954 all driers were operating. These units continue to furnish fuel as needed. As the load on the generating unit varies, two driers operating up to 100 pct of rated capacity are necessary. It is evident that the driers must have considerable flexibility to meet possible fluctuations in load.

To adjust the quantity of fuel being dried, according to plant demand, the temperature of the gases entering the drying column is regulated while constant velocity is maintained. This is accomplished by adjusting the amount of fuel burned and by changing the rate of recirculating gases. After one or two hand adjustments to increase or decrease load, the operation is regulated automatically by fuel control governed by the temperature of gases leaving the drying column. Only a few minutes are needed to change the basic load on a drier.

It has not been possible to make heat and material balances on any of the driers because the dried product cannot be weighed and the raw coal is measured by displacement of a screw feeder. The fuel burned in the furnace cannot be measured directly and must be estimated by measurement of the air and analysis of the furnace gases. A series of indirect measurements have proved that drier operation closely approximates theoretical design.

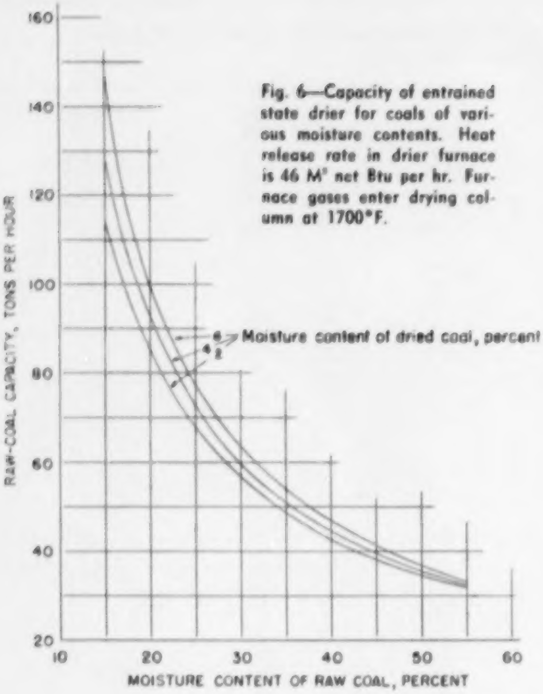

Fig. 6—Capacity of entrained state drier for coals of various moisture contents. Heat release rate in drier furnace is 46 M[6] net Btu per hr. Furnace gases enter drying column at 1700°F.

Theoretical capacity of an entrained-state drier connected to a drier furnace of 46 million Btu is shown in Fig. 6, which illustrates how drier capacity changes when coals of different moisture content are handled. Operation of large driers at West Canadian Collieries in Blairmore, Canada, has proved that they follow the theoretical curve in Fig. 6. Capacity of the smaller driers at Denver shows the same relation to moisture content of coal, and operating experience at Rockdale indicates that capacity fits this theoretical curve. By regulation of temperature and rate of recycle gas, output of the drier can be reduced to about half the maximum capacity. This permits considerable flexibility.

Thermal efficiency of driers of this type will range from about 87 to 92 pct, depending upon the amount of insulation in the plant. Thermal efficiency of the small driers at Denver ranges from 87.7 to 93.2 pct, excluding radiation.[1] Various tests have shown that thermal efficiency of the Texas driers, which are well insulated, is 90 to 92 pct. Thermal efficiency in this instance is defined as ratio of net heat required to evaporate moisture from coal at 300°F plus sensible heat in the dried coal at about 240°F to the net heat released in the furnace.

Carbonizer Operation to October 1954: The prototype carbonizer connected to one drier approximately as shown in Fig. 5 was built to test the integrated process. The operation is continuous; lignite moves through the plant in 10 to 15 min, demanding coordination and control of many operations. Engineering of the process was projected from experience with the small pilot plants, and the commercial-size unit was expanded by a factor of about 50 to 150. Many new techniques in handling fine coal and dusts must be designed and their performance checked by field operations before detailed designs are made for additional carbonizers to serve the complete plant.

The unit has operated intermittently, and initial tests indicate carbonization of 56.2 lb of dried lignite per cu ft-hr, the capacity for which the reactor was designed. From pilot-plant experience, net tar production was expected to be about 14 gal per ton of raw lignite, and this yield is indicated at the plant by measurements of the tar compared with the calculated lignite charged.

To test certain unit operations it has been necessary to operate the plant for short periods. Because the Denver pilot-plant operations were not large enough, problems posed in handling char and fine dust at 900°F must be solved in the field. Various mechanical and pneumatic methods of moving hot dusts have been investigated.

The prototype carbonizer will be operated intermittently for several months to test improvements in the several unit operations and to produce crude tar for market evaluation. Sustained operation for several weeks will be necessary to obtain data for reasonably accurate heat and material balances.

Experience has shown that yield and properties of products from the large prototype unit are similar to those from the small pilot plant. Analysis of the char is virtually the same, but its size differs from that of pilot-plant char because of degradation resulting from pneumatic transportation. It has not been feasible to collect large, truly representative samples of total crude tar produced during a given test because the tar fractions are handled through various and changing circuits and some fractions are separated for special study. The properties of total crude tar are not reported because of the experimental nature of the early tests, but spot checks on samples simulating the total crude indicate that the tar is virtually the same as that produced in the small pilot operations. Data on such tars produced at Denver are reported in the section dealing with pilot investigations.

Acknowledgments

The authors wish to acknowledge the cooperation of Texas Power & Light Co. and Aluminum Co. of America in the development of processes and release of data on plant description and operations before completion of development.

The investigation was carried out under the direction of L. C. McCabe, chief, Div. of Solid Fuels; J. H. East, Jr., regional director, Region III; and R. L. Brown, staff advisor to the chief, Div. of Solid Fuels. It was initiated under the direction of A. C. Fieldner, staff advisor to the chief, Div. of Solid Fuels of the Denver Bureau of Mines. The assistance of John B. Goodman, G. C. Lammers, Manuel Gomez, and M. S. Robinson of the Denver technical staff, Bureau of Mines, is gratefully acknowledged.

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Adsorption of Ethyl Xanthate on Pyrite

The adsorption density of ethyl xanthate on pyrite was determined as a function of xanthate concentration. Surface preparation of the mineral appears to have some effect on the subsequent adsorption process. A monolayer of xanthate on the surface is exceeded only in presence of oxygen. The effect of OH^-, HS^- (and $S^=$) and CN^- ions on the amount of xanthate adsorbed was investigated. Competition between OH^- and X^- (xanthate) ions for specific adsorption sites is indicated over a wide pH range.

by A. M. Gaudin, P. L. de Bruyn, and Olav Mellgren

IN the flotation of sulfide ores, xanthates are most commonly used to prepare the surface of the mineral to be floated so that attachment to air takes place. The quantity of agent required to make the mineral hydrophobic is usually very small, of the order of 0.1 to 0.25 lb per ton of mineral. Details of the mechanism of pyrite collection are for the most part unsettled.

Adsorption of collector has long been believed to involve an ion exchange mechanism as demonstrated for galena[1] and for chalcocite.[2] In the work on chalcocite it was also demonstrated that a film of xanthate radicals unleachable in solvents that dissolve alkali xanthates, copper xanthate, or dixanthogen was formed at the surface of the mineral. The *unleachable* product increased with increasing addition of xanthate up to a maximum corresponding to an oriented monolayer of xanthate radicals. Pyrite is extremely floatable with xanthate if its surface is fresh,[3] but the floatability decreases rapidly as oxide coatings increase in abundance. Pyrite shows zero contact angle when in contact with ethyl xanthate solution at pH higher than about 10.5;[4] at neutrality, a contact angle of 60° is obtained at a reagent concentration of 25 mg per liter. Alkali sulfides and cyanides are pyrite depressants.

In this study of pyrite collection the writers have sought to relate measured xanthate adsorption to the method used in preparing pyrite, to the presence or absence of oxygen, to concentration of hydroxyl, hydrosulfide, sulfide, and cyanide ions. The principal experimental tool has been radioanalysis,[5,6] using xanthate marked with sulfur 35.

Experimental Materials

Pyrite: Unlike most sulfides, pyrite is a polysulfide. The structure given by Bragg[7] resembles that of sodium chloride, the iron atoms corresponding to the position of sodium and pairs of sulfur atoms corresponding to the position of chlorine. The edge of the unit cell in pyrite is 5.40 A and in halite 5.63 A. The S-S distance in pyrite is 2.10 A; the Fe-S distance, 3.50 A; and the Fe-Fe distance, 3.82 A.

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Discussion of this paper, TP 4137B, may be sent (2 copies) to AIME before March 31, 1956. Manuscript, June 8, 1955. New York Meeting, February 1956. Condensed from a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Science at Massachusetts Institute of Technology, 1954.

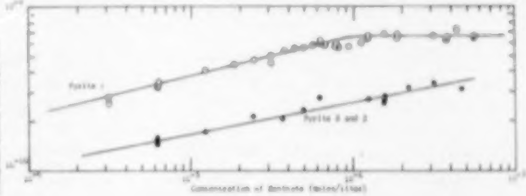

Fig. 1—Adsorption density of ethyl xanthate on pyrite as a function of the concentration of K ethyl xanthate.

Natural pyrite from Park City, Utah, was used in this investigation. Pyrite 1 was obtained by hand picking pure crystals. Pyrite 2 and Pyrite 3 were obtained from finer textured crystalline material containing inclusions of silicates. The same cleaning technique was utilized for the preparation of Pyrite 2 and Pyrite 3, whereas a different cleaning technique was used for Pyrite 1.

Pyrite 1 was prepared as follows: The crystals were ground in a porcelain ball mill and the 200/400 mesh fraction was separated by wet screening with distilled water, followed by washing for 1 hr with deoxygenated distilled water acidified with sulfuric acid to pH 1.5. The acid was removed by rinsing with deoxygenated distilled water on a filter until a pH of 6.0 was reached in the effluent. This filtration was carried out under nitrogen. The sample was then dried in a desiccator under nitrogen. The period of time for which this pyrite sample was in contact with water containing oxygen was about 4 hr. The specific surface as determined by the BET gas adsorption method was 582 cm^2 per g. Final material assayed 53.12 pct sulfur and 46.5 pct iron (theoretical, for FeS_2: S, 53.45 pct; Fe, 46.55 pct).

After crushing, Pyrite 2 and Pyrite 3 were washed with 1 M HCl, rinsed, and fed to a laboratory shaking table to remove the small amount of silicates. The concentrate obtained was ground in a laboratory steel ball mill. The 200/400 mesh fraction was separated by classification in a Richards hindered settling tube. This fraction was then given a final wash with 0.1 M HCl and deoxygenated water was filtered through the sample. The final effluent showed a conductivity equivalent to that of a solution having a salt concentration of 0.3 ppm. Aqueous hydrogen sulfide solution was then added to the sample (about 100 ml saturated H_2S solution to about 1000 g pyrite under a few hundred milliliters of water) which was stored wet under nitrogen. The sample stored in this manner showed no indication of formation of iron oxides, whereas iron oxides appeared

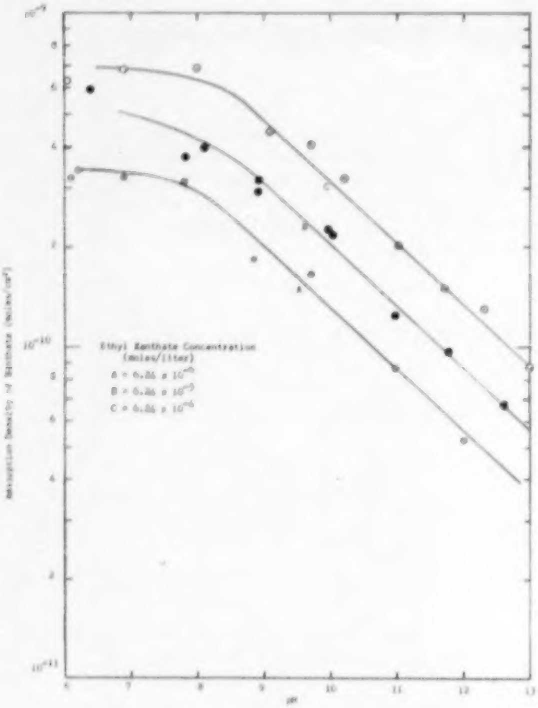

Fig. 2—Effect of pH on the adsorption density of ethyl xanthate at constant concentration of xanthate in solution.

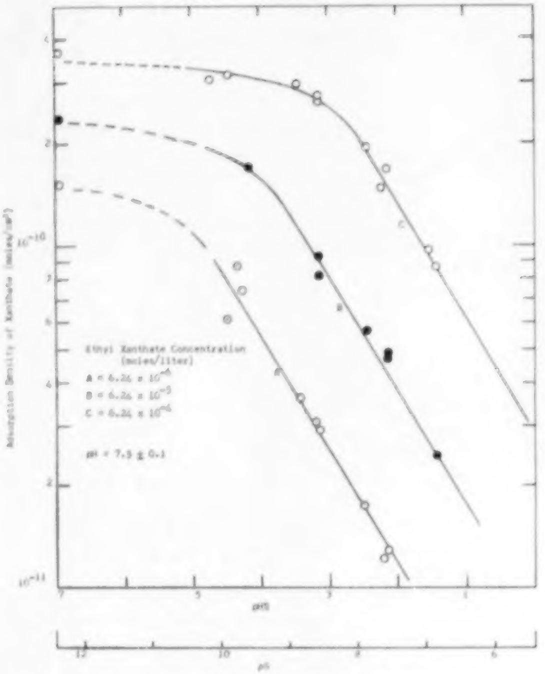

Fig. 3—Effect of pHS or pS on the adsorption density of ethyl xanthate at constant pH and constant xanthate concentration in solution.

on a similar sample stored in the absence of hydrogen sulfide.

The specific surface of Pyrite 2 was 345 cm^2 per g; it contained 53.09 pct sulfur and 46.57 pct iron. Pyrite 3 is a finer material prepared in exactly the same way. Its specific surface was 535 cm^2 per g and it contained 53.01 pct sulfur and 46.45 pct iron.

Since hydrochloric acid was used in the cleaning step of Pyrite 2 and Pyrite 3, a brief study was made using radiochlorine (as chloride) to find out whether adsorbed chloride was readily desorbed. Experiments showed that chloride was not retained at all by well washed pyrite.

Potassium Ethyl Xanthate: The xanthate used in this work, containing some molecules marked with S35, was purified in the usual way.[9] In addition, the following steps were taken to prevent rapid decomposition: The xanthate precipitated with ether from acetone solution was allowed to settle and the supernatant liquid was decanted. The precipitate was then collected on a porcelain filter and washed with ether, care being taken to keep it covered with ether at all times. The precipitate, suspended in the residual ether, was then poured into the stock bottle and centrifuged. The excess ether was decanted and the bottle placed in a desiccator, where the product was dried and stored under vacuum at about 0°C. To prevent condensation of water vapor, the desiccator was never opened before it had reached room temperature. Although it appeared unchanged, the xanthate used in this research was repurified at least every two months.

All other reagents were of reagent grade. Details of the preparation of the hydrogen sulfide solution are given in a thesis by Mellgren.[9]

Adsorption Measurements: Two experimental methods have been used by earlier investigators for determining quantitatively the adsorption density of collector on mineral surfaces, namely, the agitation method and the column method.[10] The column method was chosen to minimize analytical work.

Adsorption apparatus used in this investigation was similar to that used by previous investigators.[10-13] The pyrite sample (5 to 10 g) was placed in a Buechner funnel of small diameter. This was connected through a pyrex ball and socket joint to the separatory funnel, which contained the feed solution under a nitrogen atmosphere. The effluent solution passed through a tygon tube into a filter flask. A series of these adsorption units were connected in parallel to a pyrex glass manifold through which purified nitrogen passed under a slight positive pressure. The nitrogen was purified by flowing tank nitrogen through a Vicor tube containing copper gauze at 500°C. The exit gas after passing through a liquid air trap then bubbled through two wash bottles filled with pyrogallic acid solutions (1 liter each). After passing through another trap the gas was scrubbed in a wash bottle filled with deoxygenated water and then flowed through a third trap to the manifold. All glass connections were made with tygon tubing. The test solutions were transferred from volumetric flasks to the separatory funnels under nitrogen.

The method of radioanalysis involves the oxidation of xanthate sulfur to sulfate with alkaline bromine solution and the subsequent precipitation of the sulfate as barium sulfate.[14]

To establish that complete oxidation of xanthate on pyrite was obtained by the analytical procedure adopted, the following tests were conducted. A deoxygenated xanthate solution (450 ml) containing 5 mg xanthate per liter was passed through 5 g of pyrite at about pH 8; the radioactivities of the in-

fluent, effluent, and mineral were measured and an activity balance was struck. The experiment, repeated four times, showed in each case that the spread between the activity on the pyrite as calculated by difference from the radioanalysis of the influent and effluent solutions and the activity measured experimentally was less than 2 pct. This shows that the xanthate on the pyrite can be removed quantitatively from the mineral by the bromine-oxidation step of the analytical procedure. It shows also the reproducibility of the analysis.

Because xanthate decomposed at low pH,[16-17] the influence of this decomposition on the radioassay was studied. Two xanthate solutions were prepared. Solution 1 was made from water saturated with oxygen at room temperature and was stored in a closed container. Initial xanthate concentration of this essentially neutral solution was 5 mg per liter. The solution was radioassayed on preparation and also after standing for 28 hr. Solution 2 was prepared from deoxygenated water and contained 100 mg per liter of xanthate. Aliquot samples of this solution were acidified with different amounts of hydrochloric acid. Solution 2 was radioassayed on preparation; the different aliquots were radioassayed after 5 hr of standing and the pH values determined at the end of this period. As may be seen from Table I, the loss of activity increases with decreasing pH and is large even in dilute acid solutions. Since any decomposition product remaining in solution would be detected, radioactive sulfur must have been lost to the gaseous phase as a sulfur-bearing gas. Table I also shows that at neutral pH values at least, oxygen does not appear to be involved in this decomposition reaction.

Results

Influence of Oxygen: Early adsorption experiments were made with Pyrite 1 and aqueous solutions of xanthate which were not deoxygenated. Enormous acquisition of radioactivity by the pyrite was observed. In two tests, 1.5 liters of solution containing respectively 4.23×10^{-4} and 4.37×10^{-4} mols per liter at neutral pH were used and the adsorption densities were 3.21×10^{-9} and 1.68×10^{-9} mols per cm^2. The amount of xanthate abstracted is much greater than that calculated for a monolayer (6.8×10^{-10} mols per cm^2) on the basis of a cross-sectional area of 25 A^2 per xanthate radical.*

* This value is midway between a value of 27 A^2 suggested by Gaudin and Preller[12] and a value of 23 A^2 used by Gaudin and Schuhmann.[3]

The influent and effluent solutions in these two tests were examined in an intense beam of light. A Tyndall cone was observed in the effluent solution, suggesting the presence of minute oily droplets. No evidence of turbidity was noted in the influent solutions. Experiments conducted under the same conditions but without pyrite in the Buechner funnel showed no cloudiness in the effluent. These observations suggest that pyrite might play a part in making possible the oxidation of xanthate by dissolved oxygen and that some sulfur-bearing reaction product adheres to the pyrite while the rest is flushed away in the effluent. No further study was made of this observation, but it deserves more attention.

With the same pyrite provided the xanthate was dissolved in deoxygenated water; the radio-sulfur activity acquired by the pyrite corresponded to less than a monolayer of xanthate. Taken collectively,

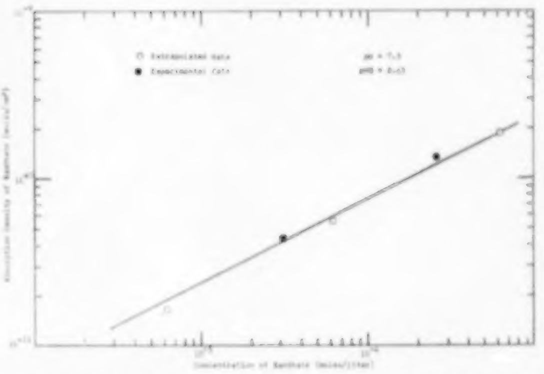

Fig. 4—Adsorption density of xanthate as a function of K ethyl xanthate concentration at constant pH and pHS.

these experiments strongly suggest that dissolved oxygen plays a major part in this flotation system.

Equilibrium and Reversibility: Several early experiments were made to find the least volume of a xanthate solution that had to be passed through the mineral bed to approach an equilibrium xanthate coating. These tests suggested that passage of solution in the amount of 2 liters per experiment would be adequate to approach equilibrium from below, and this volume was usually employed in the work.

The equilibrium adsorption for a given concentration of agent in solution may be ascertained more satisfactorily by approaching it from above in addition to approaching it from below. Several series of tests were conducted[9] to make sure that the measurements represent equilibrium conditions. These tests were made both at different pH values and in the presence of added alkali sulfide. Some of the tests, especially on Pyrite 1, indicated fair agreement between the expected activity and the realized activity on the samples subjected to desorption. Other tests, however, especially on Pyrite 3 in the presence of

Table I. Decomposition of Acidified Xanthate Solutions

Description	Time of Analysis, Hr	pH	Activity, Cpm
Solution 1	0		1958
5 mg xanthate	0		1961
per liter;	28	6.2	1663
oxygen not removed	28	6.2	1678
from water			
Solution 2	0	6.8	2609
100 mg per	5	6.0	2542
liter xanthate;	5	3.75	60
oxygen removed	5	2.63	25
from water	5	2.00	nil
	5	1.20	nil

sulfide ion, did not show satisfactory agreement. Complete reversibility of xanthate adsorption, therefore, has not been proven in all cases.

Adsorption Density as a Function of Xanthate Concentration: Measurements were made with potassium ethyl xanthate and the three samples of pyrite. Experimental results are presented in Fig. 1. It is seen that the data for Pyrite 1 fall on one curve and those for Pyrite 2 and Pyrite 3 on another.

No attempt was made to control the temperature during the adsorption measurements. Fortuitous variations in temperature from 20° to 27°C do not appear to have a systematic effect on the data. The solutions used in these experiments were not buffered; the measured pH varied from 6 to 7 with the

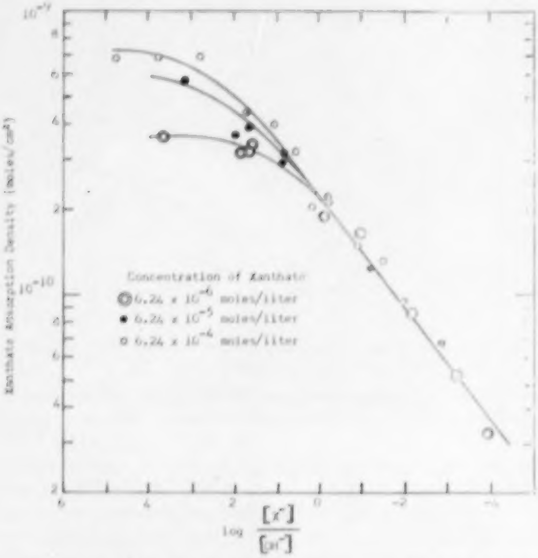

Fig. 5—Xanthate adsorption density as a function of the ratio of xanthate to hydroxyl ion concentration.

highest values recorded at the highest xanthate concentrations. These small variations in pH did not cause any systematic variation in the results. The ionic strength of the solution was not kept constant but was mainly determined by the concentration of xanthate used.

Fig. 1 shows that experimental points for Pyrite 1 follow a straight line with a slope of one quarter in the 300-fold concentration range, which is 3×10^{-6} to 9×10^{-4} mols per liter. One adsorption value, 1.5×10^{-10} mols per cm^2, at a concentration of 3×10^{-7} mols per liter, is not included in Fig. 1. If this point is taken into account, the straight line appears to extend over a 300-fold concentration range.

For concentrations larger than about 1.2×10^{-4} mols per liter the adsorption density appears to be independent of xanthate concentration at about 6.8×10^{-10} mols per cm^2.

The adsorption curve for Pyrites 2 and 3 is displaced in the direction of lower adsorption values with respect to the curve for Pyrite 1. The experimental results on Pyrites 2 and 3 are spread around a straight line with a slope of about one fifth, and within the concentration range covered, no complete independence of surface concentration on solution concentration is indicated.

The reason the two curves are displaced may be found in the preparation of the pyrite samples: Pyrite 2 (although exposed to oxygen for a longer period of time than Pyrite 1) was stored in hydrogen sulfide solution, a depressor for sulfide minerals, whereas Pyrite 1 was not exposed to hydrogen sulfide and was stored dry. Possibly some of the sulfide ion remained on the mineral during exposure of Pyrites 2 and 3 to the xanthate solutions so that curves for those mineral samples represent adsorption measurements for xanthate ion in the presence of a small but undetermined concentration of sulfide ion.

If it is assumed that each xanthate group covers an area of 25 A^2, which is intermediate between previously made assumptions of 23 A^2 and 27 A^2,[8, 10] a monolayer would require 6.8×10^{-10} mols per cm^2 of xanthate. This saturation value happens to agree quite closely with the maximal value for adsorption on Pyrite 1. Contact angle studies of ethyl xanthate on pyrite by Wark[4] show that a maximum contact angle is reached at a concentration of about 25 mg of xanthate per liter. This concentration is in good agreement with the concentration at which the maximum adsorption density appears on the adsorption-concentration curve for Pyrite 1.

The curve for Pyrite 1 represents a surface coverage ranging from 40 pct at 3×10^{-6} mols per liter (0.5 mg/1) to 100 pct for concentrations above 1.2 $\times 10^{-4}$ mols per liter (20 mg/1). A surface coverage ranging from 22 to 47 pct is shown by the curve for Pyrites 2 and 3 over the same concentration range.

Effect of pH on the Adsorption Density: The change in the adsorption density of xanthate on Pyrite 1 with pH for three different collector concentrations (A:1, B:10, and C:100 mg/1) is shown in Fig. 2. The pH was controlled with potassium hydroxide, and since no buffer solutions were used, the experimental values in the range pH 6 to 9 are not accurately determined. In these tests the temperature varied between 20° and 25°C. Fig. 2 shows that changes in adsorption density with pH for pH values between 6 and 8 are small and that the adsorption density decreases with increasing pH from about pH 8 to 13. The logarithm of the adsorption density appears to be linearly related to pH for pH values larger than 9, the slope of this line being about 0.2.

Fig. 2 also shows that for constant adsorption density of xanthate a tenfold increase in hydroxyl ion concentration requires also a tenfold increase in the collector concentration.

The surface coverage decreases from about 50 to 4 pct upon increasing pH from 6 to 13 at constant xanthate concentration of 6.24×10^{-6} mols per liter (1 mg/1). The corresponding changes in surface coverage at a constant xanthate concentration of 6.24×10^{-5} and 6.24×10^{-4} mols per liter (10 and 100 mg/1) are 80 to 6 pct and 100 to 12 pct.

Effect of Hydrosulfide and Sulfide Ion on the Adsorption of Xanthate: Measurements were made of the adsorption of xanthate on Pyrite 2 in the presence of various concentrations of hydrosulfide ion. The xanthate concentrations were 1, 10, and 100 mg per liter, so that three sets of data are available.

Table II. Effect of Cyanide on the Adsorption Density of Xanthate on Pyrite 3 at a Constant Xanthate Concentration of 6.24×10^{-5}

pCN	pH	pOH	Adsorption Density, Mols per Cm^2
3.18	9.95	4.05	0.19×10^{-10}
* 3.91	9.52	4.48	0.35×10^{-10}
* 3.89	9.60	4.40	0.25×10^{-10}
5.17	8.60	5.40	0.74×10^{-10}
	7.4	6.6	1.84×10^{-10}
	7.6	6.4	1.74×10^{-10}
	8.85	5.15	1.58×10^{-10}
	11.65	2.35	0.42×10^{-10}

* Duplicate tests.

Measurements were made at 24.5 ± 1.5°C and at pH 7.5 ± 0.1. The $[HS^-]$ and $[S^=]$ were calculated from the pH and from the concentration of total sulfide sulfur (as H_2S, HS^-, and $S^=$) as determined analytically, using the two dissociation constants of H_2S:[10]

$$H_2S \rightleftharpoons HS^- + H^+;\ K_1 = 1.02 \times 10^{-7}$$
$$HS^- \rightleftharpoons H^+ + S^=;\ K_2 = 1.3 \times 10^{-13}$$

Fig. 3 shows the results obtained. The results are expressed in terms of pHS as abscissae. The symbol pHS is defined in the same way as pH. In fact, since the data were obtained at the constant pH = 7.5 the ratio $[HS^-]:[S^=]$ is constant, and the abscissae may be changed to pS by a mere translation of scales (bottom scale of abscissae, Fig. 3).

Fig. 3 shows that the adsorption density of xanthate on pyrite decreases with increasing concentration of sulfide or hydrosulfide ions. In the upper range of HS^- and $S^=$ concentrations covered in this investigation, the logarithm of xanthate adsorption is linearly related to pHS and pS within experimental error. The three straight lines have the same slope of about one third. It is interesting to note that this straight line relation prevails below pHS values of respectively 4.5, 3.5, and 2.5 for constant xanthate concentrations of 6.24×10^{-6}, 6.24×10^{-5}, and 6.24×10^{-4} mols per liter.

Above the limiting pHS value of 2.5 for curve C the effect of $[HS^-]$ on xanthate adsorption becomes much less marked. The curve flattens out and is seen to approach a maximum adsorption value equivalent to the adsorption density obtained on Pyrite 2 when no sulfide or hydrosulfide is *deliberately* added to the solution (Fig. 1, lower curve). This limiting value is plotted on the ordinate axis in Fig. 3; similar values are likewise plotted for the other two xanthate concentrations. All three curves in Fig. 3 should lie below the respective limiting values suggested by Fig. 1, since the pH of the systems represented in Fig. 3 is approximately one unit higher than the pH at which the curves in Fig. 1 were determined. This is borne out by the data.

In Fig. 4 is presented an adsorption curve for xanthate on Pyrite 2 at a constant pH of 7.5 and a constant pHS of 2.45. Three of the points on this line were obtained by interpolation from the data in Fig. 3 and the other two by direct experimentation. The slope of the straight line drawn through the points is about one half. Fig. 4 is of importance because the adsorption results were obtained under conditions where a positive control was exerted on the concentration of those ionic components (OH^-, X^- and $S^=$ or HS^-) which are known to play a major role in pyrite flotation systems.

Effect of Cyanide on the Adsorption Density of Xanthate: A few tests were conducted to evaluate the magnitude of the effect of cyanide on the adsorption of xanthate on Pyrite 3. The xanthate solution concentration was kept constant at 6.24×10^{-5} mols per liter (10 mg per liter). In Table II the adsorption density at each free cyanide ion concentration expressed as pCN is given.

Since pH was not kept constant in these tests, the pH of each solution is also given. The free cyanide ion concentration was calculated from a knowledge of the total amount of cyanide added, the pH, and the dissociation constant for HCN (7.2×10^{-10}), a negligibly small concentration of iron in solution being assumed. In addition to results obtained in the presence of cyanide a few scattered results on the effect of pOH on xanthate adsorption on Pyrite 3 in the absence of cyanide are included in Table II.

Table II shows that with increasing cyanide ion concentration there is a steady decrease in the adsorption density of xanthate. Even though it is not possible to separate completely the effect of cyanide from that of pOH, the data in Table II show that in the presence of cyanide the adsorption of xanthate is more limited than in its absence.

Summary of Adsorption Measurements: If oxidation is prevented during exposure of pyrite to aqueous xanthate, the mineral abstracts xanthate up to formation of a monolayer. The adsorption density is greatly reduced by hydroxyl, hydrosulfide (and/or sulfide) and cyanide ion. The adsorption-depressing properties of hydroxyl, hydrosulfide, and cyanide ions are similar, although cyanide seems most effective and hydrosulfide weakest.

If oxygen is present during exposure of pyrite to xanthate, abstraction of xanthate sulfur is much increased, even to greatly exceeding a monolayer.

Experimental difficulties have been so great that complete proof of reversibility of xanthate adsorption in all cases is still lacking.

Discussion

Competition Between Xanthate and Hydroxyl Ion: The data on xanthate adsorption in the presence of various concentrations of hydroxyl and hydrosulfide ions shed some light on the adsorption mechanism.

Thus Fig. 2 suggests that increased xanthate concentration is more or less equivalent to increased hydroxyl concentration. This is made clearer by Fig. 5 in which xanthate adsorption is plotted against the ratio of xanthate ion to hydroxyl ion (both scales being logarithmic). Fig. 5 shows that at low $\frac{[X^-]}{[OH^-]}$ ratios, Γ_{x^-} depends on that ratio and not the particular xanthate ion concentration used. This is not true at high $\frac{[X^-]}{[OH^-]}$ ratios. In other words, at low $\frac{[X^-]}{[OH^-]}$ ratio, xanthate and hydroxyl ions are competitive, but this is not true when the ratio is large.

Similar ideas might be entertained regarding the competitiveness of hydrosulfide and xanthate ions. However, charting the data of Fig. 3 with $\frac{[X^-]}{[HS^-]}$ as abscissae does not bring all the points on a single line. To some extent this effect may be the result of hydroxyl ion, which is always present. The authors feel that the matter is best left unsettled in view of the inadequacy of experimental knowledge.

Returning to Fig. 5, it is noteworthy that the slope of the line relating log Γ_{x^-} to log $\frac{[X^-]}{[OH^-]}$ is only about 0.2. If the assumption is made that there is a stoichiometric ion exchange between OH^- and X^- at the surface of pyrite at constant exchange capacity, and if the further assumption is made that the activities of the reacting ionic species at the surface and in the solution are equal to the respective concentrations, the conclusion emerges[30] that

$$\frac{\Gamma_{x^-}}{\Gamma_{OH^-}} = \frac{\Gamma_{x^-}}{\Gamma_0 - \Gamma_{x^-}} = K\frac{[X^-]}{[OH^-]}$$

where Γ_0 is the number of sites available for exchange. If Γ_{x^-} is small compared to $(\Gamma_{x^-} + \Gamma_{OH^-})$, the xanthate adsorption should be proportional to the ratio of xanthate to hydroxyl ion concentrations. This is manifestly not the case, since Γ_{x^-} varies as the 0.2 power of $\frac{[X^-]}{[OH^-]}$ instead of as the first power. Accordingly, either the assumption regarding the values of the activity coefficients is not reasonable (particularly in regard to the activity coefficients in the adsorbed state), or else the competitive ex-

change mechanism is not so simple as assumed here.

The conclusion that the xanthate adsorption depends on the ratio of xanthate concentration to that of hydroxyl ion concentration (Fig. 5) is in line with the data of Wark and Cox[21] and with the interpretation by Barsky[22] of the significance of critical pH curves.

Acknowledgments

It is a pleasure to record the benefit we have received from the discussions of the work with our colleagues, particularly Professors J. Th. G. Overbeek and Carl Wagner, and to express our appreciation for financial support to the Research Div., U. S. Atomic Energy Commission.

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Geophysical Investigations in the Central Portion Of Michigan's Upper Peninsula

by Gordon E. Frantti

UNDER the auspices of the Geophysical Committee of Michigan College of Mining and Technology, an investigation was made in Michigan's Upper Peninsula to obtain geophysical data* related to the regional subsurface geology in the area covered by Paleozoic sediments. The area surveyed includes that portion of the Upper Peninsula which lies between R18W to R26W and T41N and T49N, covering approximately 1300 square miles. On the index map, Fig. 1, it is represented by the cross-hatched zone west of Munising. Four of the five sites of detailed investigation are indicated by the letters *A*, *B*, *C*, and *D*.

* Calculations and profiles referred to, but omitted in this paper, are on file in a Master of Science thesis[1] at Michigan College of Mining and Technology.

A detailed gravity and magnetic survey had previously been conducted by J. G. Wilson[2] near Perkins, 8 miles north of Rapid River, on a local anomalous area. Results of his work, which showed a large positive magnetic anomaly associated with a gravity anomaly, aroused interest in the possible economic significance of the formations underlying the Paleozoic sediments in this part of the Upper Peninsula.

Early in the 1900's the Michigan Geological Survey, as well as many private companies, had done a considerable amount of dip needle work near the southwest corner of the area discussed in this paper.

G. E. FRANTTI, formerly an Engineer with Copper Range Co., Michigan, is now a Geologist with Cleveland-Cliffs Iron Co.

Discussion of this paper, TP 4163L, may be sent (2 copies) to AIME before Mar. 31, 1956. Manuscript, April 22, 1955. Chicago Meeting, February 1955.

Most of the information available to the writer was obtained from indicated magnetic anomalies on the geological map of the northern peninsula of Michigan.[3] Results of the geophysical activities of mining companies in the vicinity of the Marquette range and Gwinn district were unavailable to the author.

Physiography and Geography: The region under consideration has low to moderate relief. About half the area is comprised of swampy lowlands, and because of the swamps and forests much of the land is almost inaccessible. The major drainage system is dendritic, with streams flowing into Lake Michigan on the south and Lake Superior on the north. The general geology, shown in Fig. 2, indicates an overlay of Paleozoic sediments on pre-Cambrian formations along a line running approximately south from Marquette (not shown on the geological map). Actual contact between pre-Cambrian and Paleozoic sediments is not known because most of the area is covered with glacial till, and outcrops are very scarce. Exposures of the Paleozoic sediments show that these beds in the northern areas dip gently under Lake Superior and that in the southern areas they dip gently to the southeast. Outcroppings of the pre-Cambrian formations occur primarily to the west of the surveyed area except in the northwest corner where the Laurentian series outcrop as far east as the Gwinn district and also in T46N, R24W.

Instrumentation: Gravity measurements were made with the Worden portable gravity meter. Since this was chiefly a reconnaissance regional survey, both the large and small dials were used. The instrument used had a constant of 0.0035 milligals per scale division, a working range of about 25 milligals.

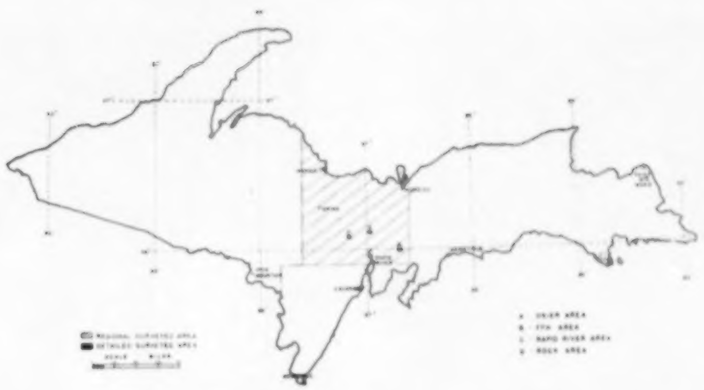

Fig. 1—Index map of the Upper Peninsula of Michigan. The area surveyed covers approximately 1300 square miles.

Base checks using the large and small dials in conjunction indicated that probable precision of measurement was of the order of ± 0.05 milligals for the regional survey. Bouguer gravity values are relative to the gravity pendulum station at Iron River, Mich. All necessary corrections were made to obtain the Bouguer gravity, except that no terrain correction was applied. Gravity stations were occupied at about 1-mile intervals along roads that form the traverse lines.

Magnetic measurements were made with a Schmidt Askania temperature-compensated vertical magnetometer having a scale constant of 24.8 gammas per division. When necessary, the range of this instrument was extended by means of three calibrated auxiliary magnets. All magnetic readings are relative to the magnetic base station of the Cleveland-Cliffs Iron Co. A value of 56,000 gammas was used for this station, which is two miles northwest of Ishpeming.

Elevation Control: Elevations for gravity stations located along highways were obtained from the Michigan State Highway surveys. Additional elevations were obtained by use of an American-Paulin altimeter in conjunction with a precision recording base microbarograph which monitored fluctuations in air pressure. By previous investigation the probable error of elevations obtained in this manner was found to be ± 5 ft as long as the altimeter was used within 20 miles of the microbarograph. This error in elevation was considered within the required precision for the regional gravity survey.

Interpretation of Results

Regional Anomalies: As indicated in the Bouguer gravity map, Fig. 3, there is one major regional gravity anomaly extending from the northwest portion of the area southeastward to the east central portion of the map. This positive gravity *high* has a magnitude of the order of 20 milligals. The author's investigations[1] indicated that this gravity anomaly extends southeastward into the vicinity of St. Ignace. Similarly there is a slight magnetic high apparent on the isomagnetic map which extends eastward from the northwest corner of the region, continuing to the vicinity of St. Ignace. The features of profiles drawn across these anomalies plus the coincidence with a large Laurentian granite outcrop in T46N, R24W indicate that this anomaly is the result of a structural feature which is probably the dividing line between the Lake Superior and Lake Michigan basins.

South of this regional gravity high, which is near the Alger-Delta county line, are a number of smaller anomalies within the very large negative gravity anomaly which extends southward into Lake Michigan. This area also shows a considerable amount of magnetic disturbance, as is indicated on the isomagnetic map, Fig. 4. The following section discusses briefly the anomalies in these smaller areas.

Local Anomalous Areas: The area outlined on the index map contains four local anomalies indicated by the letters *A*, *B*, *C*, and *D*. These anomalies do not include the very large magnetic anomaly located eight miles north of Rapid River. The latter had been investigated previously by Wilson.[1]

Taken as a whole, the magnetic anomalies shown in the lower half of the mapped region indicate a large magnetic nose centered in T42N, R23W with the limbs extending to the northwestward and southeastward. Considering this in conjunction with the corresponding Bouguer gravity anomaly, there is an indication of a structural feature bearing a reverse fold near the south central portion of the surveyed region. This feature could be clarified if additional work were done in the regions of scarce data.

The greatest significance of these anomalies lies in the possibility that they might be related to an iron-bearing formation within the pre-Cambrian rocks which lie at a considerable depth below the Paleozoic sediments. Wilson's calculations[2] based on the anomaly north of Rapid River indicated that the depth to the anomaly-producing source there was of the order of 1000 ft. Calculations by the author on

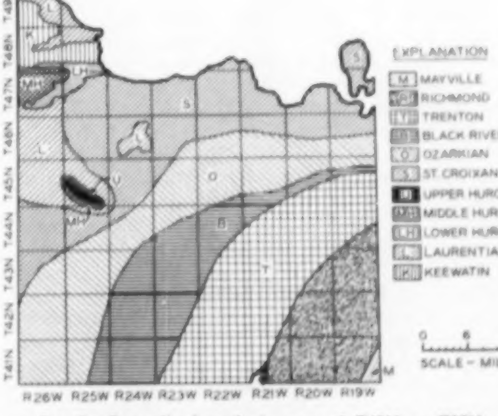

Fig. 2—Generalized geologic map of T41N to T50N and R26W to R19W. (After geologic map of Upper Peninsula of Michigan 1936).

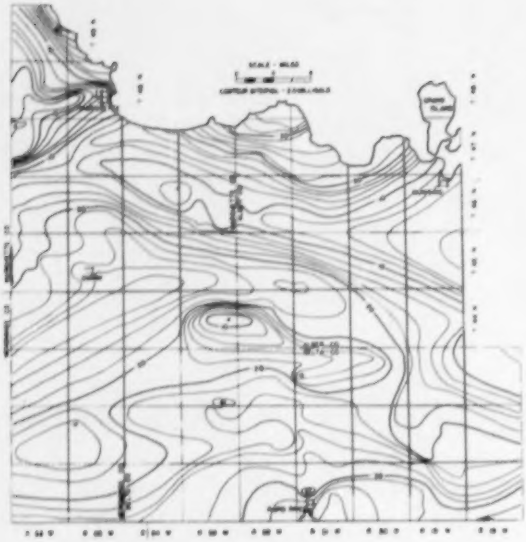

Fig. 3—Bouguer gravity map of T41N to T49N and R18W to R26W, Upper Peninsula of Michigan.

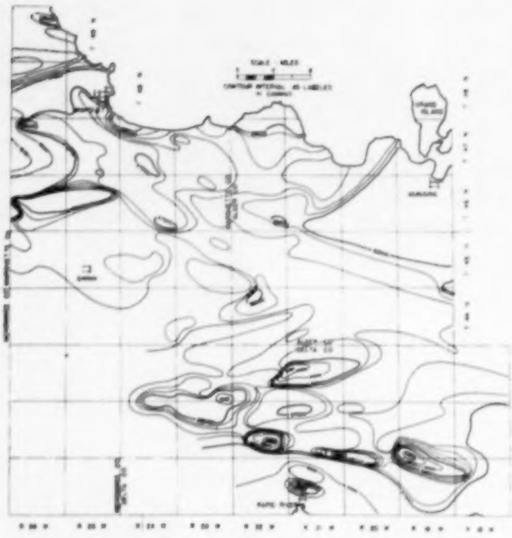

Fig. 4—Isomagnetic map of T41N to T49N and R18W to R26W, Upper Peninsula of Michigan.

anomalies at *A*, *B*, *C*, and *D* indicate a similar order of magnitude in depth to the producing structure. A very interesting feature of the anomalies is that in all cases a gravity anomaly is associated with the magnetic anomalies. The gravity anomaly may be as large as 3 milligals, positive. In most cases, especially in the area investigated by Wilson[2] and areas *A* and *B* of this paper, the magnetic anomalies occur approximately at the inflection point of the gravity anomaly. This fact leads the author to suggest that the magnetic anomalies probably are the result of an iron-bearing formation lying between two other formations which have a large density contrast. This feature was more readily observable from plotted profiles. A considerable amount of detailed work was done in the vicinity of each of the anomalies *A*, *B*, *C*, and *D*. Most of these values were recorded on the regional maps and all of them were employed as controls for the contour lines.

The writer wishes to draw special attention to the gravity anomaly occurring in T44N, R23W. This anomaly lies southeast of the Gwinn district along the extended axis of this district and could very well be an extension of the Gwinn mineralized area. Although the Gwinn vicinity does not show a marked gravity high, there is an indication of a 1 milligal anomaly by the nosing of the contour pattern.

The work of Bacon and Wyble[4] in the Iron River district of Michigan, as well as that of the author[1] in the Marquette district, indicates that a positive gravity anomaly is associated with Huronian sediments. It is postulated here that the gravity anomaly shown in T44N, R23W may be the result of a small synclinal basin composed of Huronian sediments lying within the pre-Cambrian basement below the Paleozoic sediments. Although this postulation is based on a limited supply of information, it is believed by the author that this is a very favorable area for further exploration.

The isomagnetic map reveals that most of the significant magnetic anomalies are of the order of six miles in length. These anomalies trend approximately east-west and were discovered by north-south traverses. If the traverses are not spaced closer than six miles, a considerable number of anomalies might be completely overlooked. Therefore an estimate was made based upon the number of north-south traverses that were run and upon the possibility of intersecting anomalies of this magnitude with them. It was calculated that for the southern two thirds of the region shown on the magnetic map there should be ten or more magnetic anomalies such as those indicated. Much work must still be done before a reliable estimate of the subsurface geologic structure can be made. This can bear considerable influence on the economic significance of the area overlain by Paleozoic sediments.

Conclusions

The regional gravity investigations in the area bounded by T41N to T49N and R18W to R26W furnish considerable information on the subsurface geologic structure. The regional anomalies indicate the dividing line between the Lake Superior and Lake Michigan basins. The more local gravity and magnetic anomalies indicate the possibility of there being iron formation of apparent economic significance lying beneath the Paleozoic sediments in an area not previously considered significant by mineral industries. Although the estimated depth to the anomaly-producing structure is of the order of 1000 ft, much of this area appears to be potential mineral-bearing land.

Acknowledgments

The writer expresses appreciation to the Geophysical Committee of the Michigan College of Mining and Technology, which sponsored the study of this region, and to Lloyal O. Bacon, professor of geophysics, for his suggestions during the work and in the preparation of this paper.

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aime news

1956 ANNUAL MEETING

— technical program, page 75

On to New York! That's the word for February as final details of the 1956 Annual Meeting become available. Meeting dates are officially February 20 to 23, but MIED will get the ball rolling with a get-together for the educators at Columbia University on Sunday, February 19. Almost all divisions will meet Monday morning and several have a session scheduled for Thursday afternoon—making the meeting a full four-day event.

Mining Branch sessions, meetings, and social events, as well as the Welcoming Luncheon and Informal Dance, are at the Statler, while the Annual Banquet will be held at the Waldorf.

Session Highlights

For the preparation specialist the Coal Div. offers a two-session symposium built around the topic, "Planning a Coal Preparation Plant," which should draw high attendance. At other sessions, members will get the latest data on such problems as coal mining methods, continuous mining machines, materials handling, and on utilization progress.

This year Mining studies uranium, Canada, and Latin America in special sessions, and also presents a wide range of general technical topics relating to U. S. operations. Following the Jackling Lecture, the subdivision is holding a symposium on the dewatering of Michigan's Osceola mine.

In six sessions, Geology presents 36 papers on topics including nonmetallic deposits, rare metal sources, and fundamental geologic questions. A joint session with the Mining and Geophysics Subdivisions takes up "Late Stages of Crystallization and Related Ore Deposits."

Geophysics offers an exceptionally well-balanced program this year with coverage of airborne techniques, instrument development research, radioactivity, and geochemical prospecting.

Jackling Award Lecturer Announced

The third recipient of the Daniel C. Jackling Award is Dr. James B. Macelwane, S. J., dean, St. Louis University, Institute of Technology. Father Macelwane was born in 1883 near Port Clinton, Ohio. He entered the Society of Jesus (Jesuits) in 1903 and was ordained a Catholic Priest in 1918. He graduated from St. Louis University in 1910 and holds degrees from several universities including a Ph.D. from the University of California. Father Macelwane also studied at the University of Giessen, Germany.

His first position was that of instructor in mathematics at St. John's College High School, Toledo, Ohio. Later he went to St. Louis University as an instructor in physics and in 1913 became an assistant professor of physics. From 1923 to 1925 he was assistant professor of geology and director of the Seismological Stations, University of California. Father Macelwane then returned to St. Louis as director, Central Station of the Jesuit Seismological Assn., and professor of geophysics, St. Louis University. He was dean of the Graduate School from 1927 to 1933 and became dean of the Institute of Technology in 1944. He has been chosen for offices of distinction in a number of scientific societies.

DR. JAMES B. MACELWANE, S.J.

In 1948 Father Macelwane was awarded the William Bowie Medal by the American Geophysical Union, and in 1955 received the Mendel Medal from Villanova University. He was appointed by President Eisenhower to a six-year term as a member of the National Science Board of the National Science Foundation in 1954. Father Macelwane has written many technical publications and has several inventions to his credit.

MBD lives up to its tradition of extensive technical coverage with an 11-session schedule. A joint session with Industrial Minerals takes up latest developments in the air separation of nonmetallic minerals. The MBD symposium covers organization prior to start-up and the initial operation of a new mill.

In addition to joint sessions with the geologists and with MBD, the Industrial Minerals Div. is covering industrial waters, mineral synthesis, and chemical raw materials. A panel will discuss the cement-aggregate reaction at one session.

A review of the general business situation highlights the series of four sessions on Mineral Economics and will draw interested listeners from all fields. Other papers will cover the economic influence of government, transportation, and taxation.

Schedule of Mining Branch Technical Sessions

February 20 to 23, 1956

Statler Hotel, New York

Sunday, February 19—Afternoon and Evening

MIED and IMD Education Committee—The ASEE Report on Evaluation of Engineering Education as Applied to Mineral Engineering

Monday, February 20—A.M.

Min.—Uranium
Coal—Mining Methods and Problems
MIED—Training of Engineers for Management Positions
Ind. Min.—Dimension Stone and Slate

Monday, February 20—P.M.

Min.—All-Canadian Session
Geol.—General Ore Deposits I
Coal—Continuous Mining Progress Reports Forum
Ind. Min.—Industrial Water
—Dimension Stone and Slate
MBD—Concentration I
—Material Handling and Operating Control

Tuesday, February 21—A.M.

Min.—Latin American Session
Geol.—Deposits of Rare Metal Sources
Geop.—Geophysics Annual Review—Airborne Techniques
Coal—Symposium—Planning a Coal Preparation Plant I
Ind. Min.—Panel Discussion—Cement-Aggregate Reaction
Ind. Min., MBD—Air Separation of Nonmetallic Ores
MED—Economics I
MBD—Concentration II

Tuesday, February 21—P.M.

Min., Geol., Geop.—Jackling Lecture
Min.—Symposium
Geol.—Late Stages of Crystallization and Related Ore Deposits
Coal—Symposium—Planning a Coal Preparation Plant II
MED—Economics II
MBD—Hydrometallurgy—Solution and Precipitation
—Mill Design

Wednesday, February 22—A.M.

Min.—General I
Geol.—The Nature of Ore Solutions
Geop.—Geophysical Case History, Instrument Development, Research
Coal—Materials Handling Symposium
Ind. Min.—Chemical Raw Materials
MED—Economics III
MBD—Concentration III
—Crushing and Grinding I

Wednesday, February 22—P.M.

Min.—General II
Geol., Ind. Min.—Geology of Nonmetallic Mineral Deposits
Geop.—Geophysical Studies—Radioactivity
Coal—Utilization—Carbonization
Ind. Min., Geol.—Geology of Nonmetallic Mineral Deposits
MED—Economics IV
MBD—Symposium—Starting a New Mill

Thursday, February 23—A.M.

Min.—General III
Geol.—General Ore Deposits II
Geop.—Geochemistry
Coal—Utilization—Gasification
Ind. Min.—General Session
MBD—Crushing and Grinding II
—Solids-Fluids Separation, Pyrolysis, Nonmetallic Flotation

Thursday, February 23—P.M.

Coal—General Technical
Ind. Min.—Mineral Synthesis
MBD—Robert H. Richards Award
—Cleanup Session

Social Events

Sunday, February 19

5:30 to 7:30 P.M. Mineral Industry Education Div. and IMD Education Committee Reception and Buffet Supper

Monday, February 20

12:00 Noon Welcoming Luncheon
6:00 P.M. Cocktail Party (New York mining companies, hosts)
8:00 P.M. Dinner-Smoker and Stag Dinner

Tuesday, February 21

8:00 A.M. Minerals Beneficiation Div. "Scotch Breakfast"
12:00 Noon Mining, Geology, and Geophysics Div. Luncheon
Coal Div. Luncheon
Institute of Metals Div. Executive Committee Luncheon
6:00 P.M. Branch Cocktail Parties
7:00 P.M. Branch Dinners
9:00 P.M. to 1 A.M. Informal Dance

Wednesday, February 22

12:00 Noon Industrial Minerals Div. Luncheon
Mineral Economics Div. Luncheon
Extractive Metallurgy Div. Stag Luncheon
7:00 P.M. Annual Banquet and President's Reception

Thursday, February 23

12:00 Noon Minerals Beneficiation Div. Annual Luncheon

MINING BRANCH TECHNICAL PROGRAM

(Data as of Dec. 15, 1955)

Sessions and papers are not necessarily in the order in which they will be presented.

COAL DIVISION

Mining Methods and Problems

Anthracite Mine Water Problem. By R. A. Lambert and D. H. Connelly, Pennsylvania Dept. of Mines.

A Report on Industrial Engineering in Coal Mining. By R. L. Frantz, J. W. Woomer & Associates.

Industrial Engineering in Relation to Reduction of Coal Mining Costs. By W. L. Zeller, Hurley & Zeller.

Continuous Mining Progress Reports Forum

Case History of a Goodman Coal Boring Machine. By S. Krickovic, Eastern Gas & Fuel Associates.

Case History of a Jeffrey Colmol Mining Machine. By J. N. Crichton, Johnstown Coal & Coke Co.

Case History of a Joy CM-1 Mining Machine. By W. B. Jamison, Pittsburgh Consolidation Coal Co.

Symposium—Planning A Coal Preparation Plant I

Influence of Market Demands on Coal Preparation. By J. B. Morrow, Alford, Morrow & Associates.

The Selection of Types of Cleaning Units for a Coal Preparation Plant. By W. M. Berthoff, Colorado Fuel & Iron Corp.

Formal Discussion on Jigs. By A. P. Massmann, Sinclair Coal Co.

Formal Discussion on Dense Medium Cleaning. By S. A. Miller, Republic Steel Corp.

Formal Discussion on Wet Tables and Fine Coal Rheos. By J. Griffen, Pittsburgh.

Formal Discussion on Dry Tables. By W. C. McCulloch, Roberts & Schaefer Co.

Symposium—Planning A Coal Preparation Plant II

The Selection of Dewatering and Drying Equipment. By G. H. Kennedy, Rochester & Pittsburgh Coal Co., and J. L. Walker, Jr., Heyl & Patterson Co.

Formal Discussion on Dewatering Screens. By D. R. Mitchell, Pennsylvania State University.

Formal Discussion on Centrifuges. By W. L. McMorris, Coal Preparation and Distribution, U. S. Steel Corp.

Formal Discussion on Thermal Driers. By E. R. McMillan, Northwestern Improvement Co.

The Selection of Water Clarification Equipment. By J. M. Vonfeld, Pittsburgh Coal Co.

The Influence of Quality of Circulation Water on Plant Performance. By T. M. Larimer, Clairton Coke & Coal Chemical Plant, U. S. Steel Corp.

Materials Handling Symposium

Handling of Materials Between Working Face and Portal in a Coal Mine. By A. R. Anderson, Mining Div., Jeffrey Mfg. Co., M. Cunningham, Goodman Mfg. Co., and W. Hanson, Joy Mfg. Co.

From Portal Through Preparation Plant to RR Cars, Barges, and Trucks. By E. H. Citron, Pittsburg & Midway Coal Co., and R. L. Llewellyn, Eastern Gas & Fuel Associates.

From Mine to Consumer. By J. T. Crawford, North-Western-Hanna Fuel Co., A. W. Holmes, Mining Div., Link-Belt Mfg. Co., and H. C. Lusk, Barrett, Haentjens & Co.

Research in Selecting Conveyor Idler Rolls. By Felix du Breuil, Dept. of Mineral Engrg., Pennsylvania State University, G. Radomsky, Intermountain Chemical Co., and P. Cooper, Joy Mfg. Co.

Utilization—Carbonization

Better Coke by the Thermal Treatment of Coal. By F. W. Smith, D. A. Reynolds, G. W. Birge, and D. E. Wolfson, Coal Carbonization Section, U. S. Bureau of Mines.

Study of Structural Changes of Heated Coals. By M. O. Holowaty, Inland Steel Co.

Coal to Coke Sulphur Rejection Studies, A Comparison of Data Obtained from Various Test Ovens. By E. C. Knapp and G. L. Barthauer, Pittsburgh Consolidation Coal Co.; R. J. Grace, and T. S. Spicer, Pennsylvania State University.

Utilization—Gasification

The Petrographic Composition of Two Alabama Whole Coals Compared to the Size and Density Fractions. By Reynold Q. Shotts, University of Alabama.

Recycling Unburned Residue in an Entrainment-Type Gasifier. By J. Jonakin, W. C. Harrold, C. R. McCann, and J. W. Myers, Combustion Section, U. S. Bureau of Mines.

Hydrocarbonization of Coal in an Expanded Bed. By A. P. Pipilen, R. W. Hiteshue, W. Kawa, and W. Budd, U. S. Bureau of Mines.

General Technical

Some Aspects of Permanent Support of Overburden on Coal Beds. By C. T. Holland, Virginia Polytechnic Institute, and F. L. Gaddy, U. S. Bureau of Mines.

Effects of Developments in Iron Ore Supplies and Metallurgy on Fuel Requirements. By H. Perry, J. A. DeCarlo, and E. P. Carman, Branch of Bituminous Coal Research, U. S. Bureau of Mines.

Vacuum Filtration of Coals with Surface Active Agent-Kerosene Emulsions. By S. C. Sun and H. G. Papacharalambous, Dept. of Mineral Preparation, Pennsylvania State University.

MINING SUBDIVISION

Uranium

Homestake Mines Utah Uranium. By Donald T. Delicate, Utah Div., Homestake Mining Co.

The Development of a Deep Uranium Producer. By W. H. Love, Hecla Mining Co.

Development of Mining Program for Typical Morrison Orebody. By E. M. Paris, Union Carbide Nuclear Co.

Future Uranium Utilization. By John R. Dunning, College of Engineering, Columbia University.

All-Canadian Session

Mining at United Keno Hill Mines Ltd. By R. L. Segsworth and A. E. Pike, United Keno Hill Mines Ltd.

Sherritt Gordon's Nickel Copper Mines. By Alan E. Gallie, Mining Div., Sherritt Gordon Mines Ltd.

Mine Development at Gunnar. By E. F. Evoy, Gunnar Mines Ltd.

Latin American Session

Platinum Mining in Colombia. By Patrick H. O'Neill, South American Gold & Platinum Co.

Corrosion Problems in Pumping Acid Mining Waters. By G. Reinberg and C. D. Clarke, Cerro de Pasco Corp.

Custom Iron Mining at Marcona. By Eugene A. Mills, Marcona Mining Co.

Block Caving at Braden. By R. M. Haldeman, Braden Copper Co.

General I

The Lavender Pit, Bisbee, Arizona. By Warren T. Smith, Phelps Dodge Corp.

Mining Methods at the Iron King. By H. F. Mills and L. Bombardieri, Shattuck Denn Mining Corp.

Shaft Sinking Methods at National Potash-Carlsbad, New Mexico. By E. D. Bishopp, Boulder, Colo., and C. Kremer Bain, St. Louis.

Igniter Cord for Greater Safety and Increased Efficiency in Blasting. By J. G. Finlayson, Canadian Safety Fuse Co. Ltd.

General II

Pre-session Movie—*The Ninth Element*

Modern Hydraulic Mining in Florida. By C. V. O. Hughes, Virginia-Carolina Chemical Corp.

More Rock Per Dollar From the MacIntyre Pit. By F. R. Jones, National Lead Co.

Cold Bent Steel Mine Supports. By Ralph S. Siegrist, Commercial Shearing & Stamping Co.

Mining and Milling Cobalt is No Cinch. By E. B. Douglas, Calera Mining Co.

General III

A Method for Driving Long Service Raises. By John F. Emerson and Lawson A. Wright, Union Carbide Nuclear Co.

Rock Bolting at Banner's Mineral Hill Mines. By Boyd W. Venable, Banner Mining Co.

Review of Underground Haulage Practices in Metal Mines. By S. H. Ash and L. H. McGuire, Safety Div., U. S. Bureau of Mines.

A Review of DMEA-Supported Exploration in the Pacific Northwest. By Albert E. Weissenborn and Verne C. Fryklund, Jr., U. S. Geological Survey.

(Additional papers may be listed on final program)

Jackling Lecture

(Joint Session with Geology and Geophysics Subdivisions)

Jackling Lecture. By Rev. James B. Macelwane, St. Louis University, Institute of Technology.

Symposium

Dewatering the Osceola Mine in Northern Michigan. By A. S. Kromer, C. A. Campbell, R. J. Marcotte, P. H. Ostlender, and R. R. Spencer, Calumet & Hecla Inc.

GEOLOGY SUBDIVISION

General Ore Deposits I

The Quebec-Labrador Iron Ores and Their Relation to the Sokoman Formation. By A. E. Moss and J. Schwellnus, Iron Ore Co. of Canada.

Flow Direction of Ore Solutions as an Exploration Guide at the Blyklippen Mine, East Greenland. By W. H. Gross, Ventures Ltd. and Dept. of Geology, University of Toronto.

A Critical Evaluation of the Classification of Ore Deposits of Magmatic Affiliations. By A. D. Mutch, Hardy mine, Levack, Ont.

Minor Elements in Sulfides. By Michael Fleischer, U. S. Geological Survey.

The Occurrence of Selenium in Sulfides from Sedimentary Rocks of the Western United States. By Robert G. Coleman, U. S. Geological Survey.

The FeS-ZnS Geological Thermometer. By Gunnar Kullerud, Geophysical Laboratory, Carnegie Institute of Washington.

Geology of Nonmetallic Mineral Deposits

(Joint Session with Industrial Minerals Division and Society of Economic Geologists)

Economic Geology of the Phosphate Deposits of Florida. By James B. Cathcart, U. S. Geological Survey.

Fluorspar Deposits in Coahuila, Mexico. By W. N. McAnulty, Dow Chemical Co.

Economic Geology of Salem Limestone in the Indiana Building Stone District. By John B. Patton, Indiana Geological Survey.

Quality Control in the Selective Mining of Magnesite at Gabbs, Nevada. By Conrad Martin and H. P. Willard, Western Div., Basic Refractories Inc.

Comments on the Occurrence and Origin of Phosphate in Tennessee and in the Phosphoria Formation of the West. By G. Donald Emigh, Inorganic Chemical Div., Monsanto Chemical Co.

Opal Deposits Near San Juan del Rio Queretaro, Mexico. By R. J. Holmes, Dept. of Geology, Columbia University.

Deposits of Rare Metal Sources

(Joint Session with Society of Economic Geologists)

Recent Discoveries of Niobium Minerals in Alkalic Rocks of the United States. By E. P. Kaiser, Federal Center, Denver.

The Geology of Columbium and Tantalum Deposits. By A. F. Banfield, Behre, Dolbear & Co.

Association of Rare-Earth Metals With Alkalic Rocks at Mountain Pass, California, and Other Localities. By Jerry C. Olson, U. S. Geological Survey.

The Oka Alkaline Complex and Associated Columbium Deposits. By Robert B. Rowe, Geological Survey of Canada.

Economic Geology of the Yttrium-Group Elements. By E. William Heinrich, University of Michigan.

The Nature of Ore Solutions

(Joint Session with Society of Economic Geologists)

A Geologic Interpretation of Some Aspects of the Chemistry of Ore Fluids. By R. M. Garrels, Dept. of Geology, Harvard University.

The Solubility of Solids in Gases. By G. W. Morey, The Geophysical Laboratory.

The Geochemistry and Origin of Carbon Dioxide, Water, Sulphur, and Boron in the Yellowknife Gold Deposits, Northwest Territories, Canada. By R. W. Boyle, Geological Survey of Canada.

Sulfur Isotopes and the Origin of Ore-Forming Fluids. By J. L. Kulp and W. H. Ault, Lamont Geological Observatory, Columbia University.

Composition of Fluid Inclusions. By Edwin Roedder, U. S. Geological Survey.

Mineralizing Solutions that Carry and Deposit Iron and Sulphur. By B. S. Butler, Dept. of Geology, University of Arizona.

Jackling Lecture

(Joint Session with Mining and Geophysics Subdivisions)

Late Stages of Crystallization and Related Ore Deposits

Deuteric Alteration and Its Possible Significance to Wallrock Alteration in Some Rocks of the Boulder Batholith, Montana. By George J. Neuerburg, U. S. Geological Survey.

Late-Stage Magmatic Phenomena and Vein Formation in the Northern Part of the Boulder Batholith, Montana.

Part I—Late-Stage Magmatic Phenomena. By M. R. Klepper, U. S. Geological Survey, and Forbes Robertson, University of Washington.

Part II—Notes on Vein Formation. By Forbes Robertson, and D. M. Pinckney, and M. R. Klepper, U. S. Geological Survey.

Late Eocene Metallogenetic Epoch in the Bearpaw Mountains, Montana. By W. T. Pecora, U. S. Geological Survey.

Genetic Significances of Quartz-Molybdenite Mineralization in the Butte District, Montana. By Reno H. Sales, The Anaconda Co., and Charles Meyer, University of California.

Igneous Activity and Related Ore Deposition in Peru, South America. By Willard C. Lacy, University of Arizona.

General Ore Deposits II

Structural Control of Uranium Deposits in the Zuni-Mt. Taylor Region, North West New Mexico. By John W. Gabelman, Atomic Energy Commission.

Structural Sections and the Third Dimension. By R. M. Knutson, Bertha Mineral Div., New Jersey Zinc Co.

Geological Mapping by Light Helicopter, Northwest Territories, Canada. By G. M. Wright, Geological Survey of Canada.

The Geology of the Woodrow Mine. By F. Stearns Cook and E. T. Wylie, The Anaconda Co.

Geology in Development and Mining, Southeast Missouri Lead Belt. By Frank G. Snyder and John A. Emery, St. Joseph Lead Co.

Geology and Mineralogy of the Pronto Uranium Deposit District of Algoma, Ontario. By S. W. Holmes, Pronto Uranium Mines.

GEOPHYSICS SUBDIVISION

Geophysics Annual Review

Airborne Techniques

Review of Geophysics and Geochemistry for 1955. By H. V. W. Donohoo, Columbia-Geneva Steel Div., U. S. Steel Corp.

A Reconnaissance-Detail Program for Aeromagnetic Search. By F. Woods Hinrichs, Fairchild Aerial Surveys Inc.

The Airborne Adaptation of the Nuclear Magnetic Resonance Magnetometer. By Martin E. Packard, Special Products Div., Varian Associates.

Airborne Magnetometer Profile from Olympia, Washington, to Laramie, Wyoming. By W. B. Agocs and R. R. Hartman, Aero Service Corp.

Application and Interpretation of Airborne Electromagnetic Surveys in Canada. By H. S. Scott, Photographic Survey Corp. Ltd., and D. G. MacKay, Aeromagnetic Surveys Ltd.

Jackling Lecture

(Joint Session with Mining and Geology Subdivisions)

Geophysical Case History, Instrument Development, Research

Diamond Drillhole Electrical Surveys, Oriental No. 2 Orebody, Buchans Mine. By E. A. Swanson and E. W. Perkins, Buchans Mining Co., Div. of American Smelting & Refining Co.

New Swing Current Resistivity Measurements. By Clifford C. Borden, Borden Engrg. Div., M. J. Johnson Aircraft Engrg. Co.

The Use of Electrical Transients to Measure the Static Dielectric Constant of Rocks. By George V. Keller, U. S. Geological Survey.

The Interfacial Polarization Effect of Metallic Minerals and Its Influence on the Conduction of Electricity in Rocks. By Theodore R. Madden.

Laboratory Experiments in Induced Polarization. By R. G. Van Nostrand, Magnolia Petroleum Co., and John Henkel, Zinc Corp. Pty. Ltd., Australia.

Geophysical Studies—Radioactivity

Diurnal Magnetic Variations in Medium Latitudes. By Milton Glicken, Fairchild Aerial Surveys Inc.

A Gravity Anomaly Simulator. By J. A. F. Gerrard, et al., Texas Instruments Inc.

Multiple Scattering of Gamma Rays From a Buried Point Source. By Robert J. Uffen and W. B. Muir, University of Western Ontario.

Airborne Gamma Ray Spectrometer Surveys. By Hans Lundberg, Lundberg Explorations Ltd.

Gamma Ray Logging in the Search for Uranium. By D. F. Coolbaugh, Golden, Colo.

Geochemistry

Indications from Their Isotopic Abundances of the Sources of Lead Ores. By R. D. Russell and R. M. Farquhar, University of Toronto.

Ages of Some Canadian Ore Deposits and Their Relation to Structure of the Pre-Cambrian Shield. By J. T. Wilson, University of Toronto.

Soils in Geochemical Prospecting. By H. V. Warren and R. E. Delavault, University of British Columbia.

Heavy Metals in Stream Sediment as an Exploration Guide. By H. E. Hawkes, Massachusetts Institute of Technology, and Harold Bloom, Colorado School of Mines.

Rubeanic Acid Copper Test as an Aid to Leached Outcrop Interpretation. By G. L. Sawyer, Kennco Exploration Ltd.

MINERALS BENEFICIATION DIVISION

Concentration I

Streaming Potential Studies on Quartz Flotation with Cationic Collectors. By A. M. Gaudin and D. W. Fuerstenau, Massachusetts Institute of Technology.

Flotation of Primary Uranium Minerals. By Burt C. Mariacher, Colorado School of Mines Research Foundation.

Fluorchemical Collectors in Flotation. By S. R. B. Cooke, University of Minnesota, and E. L. Talbot, Minneapolis Mining & Mfg. Co.

Flotation of Rutile, Ilmenite, and Cassiterite. By C. C. DeWitt and K. U. Patel, Michigan State University.

Concentration II

Improved Contact Angle Apparatus for Flotation Research. By Donald W. McGlashan and K. N. McLeod, Montana School of Mines.

Operation of a Humphreys Spiral Plant. By Henry D. Snedden, Humphreys Investment Co.

Flotation of Uranium Minerals. By John N. Butler, University of Nevada.

Flotation of Phosphate Ore. By S. C. Sun, Pennsylvania State University.

Concentration III

Laboratory Recovery of an Oxidized Lead Mineral from a Southeast Missouri Deposit. By M. M. Fine, U. S. Bureau of Mines, and E. J. Haug, St. Joseph Lead Co.

Ionic Size in Flotation Collection of Alkali Halides. By D. W. Fuerstenau and M. C. Fuerstenau, Massachusetts Institute of Technology.

The White Pine Concentrator. By W. A. Hamilton and Virgil Lessels, White Pine Copper Co.

Adsorption of Ethyl Xanthate on Pyrite. By A. M. Gaudin, P. L. de Bruyn, and Olav Mellgren, Massachusetts Institute of Technology.

Material Handling and Operating Control

Reagent Control in Flotation. By C. H. G. Bushell and M. Malnarich, Consolidated Mining & Smelting Co. Ltd.

Instrumentation in Milling Mesabi Iron Ores. By R. Cahill, Ramsey Engineering Co.

Tailing Disposal at Morenci Concentrator. By P. F. Allen, Phelps Dodge Corp.

Conveyor Transfer Point Redesign Using High Speed Photography. By D. J. Reed, Jr., Tennessee Coal & Iron Div., U. S. Steel Co.

Air Separation of Nonmetallic Ores

(Joint Session with Industrial Minerals Division)

Hydrometallurgy—Solution and Precipitation

Treatment of Low-Grade Scheelite Ores. By F. W. Wessel, U. S. Bureau of Mines.

New Leaching in Place at Cananea. By R. C. Weed, Cananea Consolidated Copper Co.

The Effect of Roasting on the Recovery of Uranium and Vanadium Ores by Carbonate Leaching. By J. Halpern, F. A. Forward, and A. H. Ross, University of British Columbia.

Copper Leaching and Precipitation at Anaconda's Weed Heights Plant. By A. E. Millar, The Anaconda Co.

Mill Design

Economic Determination of a Contemplated Mining and Milling Project. By James Boyd, Kennecott Copper Corp.

Interpretation of Research and Ore Test Data. By D. E. Newton and H. J. Gisler, Denver Eqpt. Co.

Flowsheets: Forms and Uses. By O. W. Walvoord, O. W. Walvoord Co.

The Owner, the Engineer, the Contractor. By J. D. Grothe, Dorr-Oliver Inc.

Crushing and Grinding I

Low Grade Iron Ore and the Aerofall Mill. By R. G. Fleck and R. E. Durocher, Jones & Laughlin Steel Corp.

Predicting Size Distribution in Classifier Products. By E. J. Roberts and E. B. Fitch, Dorr-Oliver Inc.

Gyratory Ball Mill. By A. W. Fahrenwald, University of Idaho.

Wet Cyclones in Closed-Circuit Grinding. By Richard Krebs, Equipment Engineers Inc.

Crushing and Grinding II

Grinding Practice at Chuquicamata. By D. S. Sanders, Chile Exploration Co.

Energy Transfer by Impact. By R. J. Charles and P. J. de Bruyn, MIT.

Effect of Heat Treatment and Magnetic Conversion on the Grindability of Nonmagnetic Taconites. By R. A. Person and Will Mitchell, Jr., Allis-Chalmers Mfg. Co.

Correlation of Rod Mill Capacities with Operating Variables. By Nathaniel Arbiter, Columbia University.

Symposium—Starting A New Mill

Organization Prior to Startup. By W. A. Hamilton, White Pine Copper Co., E. W. Lindroos, Republic Mining Co., and C. E. Osborn, Kerr McGee Oil Industries Co.

Actual Startup. By H. L. McNeill, Stearns-Roger Mfg. Co., and H. R. Hendricks, Silver Bell Unit, American Smelting & Refining Co.

Initial Operations. By R. H. Lowe, American Cyanamid Co., and W. A. Arpi, Oliver Iron Mining Div., U. S. Steel Corp.

Solids-Fluids Separation, Pyrolysis, and Nonmetallic Flotation

Natural and Synthetic Polyelectrolytes as Flocculants for Mineral Suspensions. By M. E. Wadsworth and I. B. Cutler, University of Utah.

Filtration and Control of Moisture Content on Taconite Concentrates. By C. F. Cornell, A. F. Dunyon, and D. A. Dahlstrom, The Eimco Corp.

FluoSolids Installation at Bethlehem's Sparrows Point Plant. By J. K. Kurtz and Harold Scharf, Bethlehem Steel Co.

Flotation of a Canadian Kyanite Ore. By R. A. Wyman, Dept. of Mines, Ottawa, Canada.

Robert H. Richards Award

Some Research in Crusher Grinding, Froth Flotation, and Emulsion Flotation. By A. W. Fahrenwald, University of Idaho.

MINERAL INDUSTRY EDUCATION DIVISION

The ASEE Report on Evaluation of Engineering Education as Applied to Mineral Engineering

(Joint Meeting with Institute of Metals Division Education Committee)

The Objectives as Applied to Mineral Engineering. Speaker to be announced.

Engineering Sciences. Speaker: B. F. Howell, Jr., Pennsylvania State University.

Humanistic-Social. Speaker: E. S. Burdell, Cooper Union.

The Future of Engineering Education. Speaker to be announced.

General Discussion of ASEE Report and the Future of Engineering Education. Speaker: Curtis L. Wilson, Missouri School of Mines.

Training of Engineers for Management Positions

The Anaconda Co. By Edward I. Renouard, Jr.
Climax Molybdenum Co. By John M. Petty.
Building Blocks for Management. By Raymond E. Byler, Arthur D. Little Inc.
Middle Management Training for Mining Engineers. By John Fayerweather, Harvard University.
University of California. By L. M. K. Boelter, University of California.

INDUSTRIAL MINERALS DIVISION

Industrial Water

The Arkansas-White-Red Basins Interagency Study of Water and Power Resources and Its Importance to the Mineral Industry. By R. S. Sanford, U. S. Bureau of Mines.
Planning of Texas Surface Water Supplies. By S. W. Freese, Fort Worth, Texas.
Ground Water for Industry (Methods and Costs of Ground Water Development). By R. G. Kazmann, Stuttgart, Ark.
Application of Waste Water Reclamation to the Mining Industry. By R. C. Merz, University of California.
Treatment and Reclamation of Waste Waters. By R. P. Logan, Dorr-Oliver Inc.
Saline Water Conversion Research. By Sidney Gottley, U. S. Bureau of Mines.

Panel Discussion—Cement-Aggregate Reaction

(Names of members of the panel to be announced)

Air Separation of Nonmetallic Ores

(Joint Session with Minerals Beneficiation Division)

Introduction. By A. L. Hall, Cabot Carbon Co.
Grinding and Classifying to Precise Specifications in the Sub-Sieve Range. By William H. Lykken, Hurricane Pulverizer Co.
Meeting the Engineers' Challenge for Better Fine Particle Air Classification. By Alan R. Lukens, Lukens Laboratories Inc.
New Principles and Results in Air Classification. By Robert E. Payne, Sharples Corp.

Mineral Synthesis

Synthetic Crystals, A New Tool for Research Process Controls, and Mineralogical Survey. By E. C. Stewart, Harshaw Chemical Corp.
Synthesis of Some Ferrites. By H. H. Kedesdy and A. Tauber, Signal Corps Engineering Laboratories.
Synthetic Mica Goes Into Commercial Production. By R. A. Humphrey, Synthetic Mica Corp.
Synthetic Hydro-Fluoro Silicates. By Alvin Van Valkenburg, National Bureau of Standards.
Production of Synthetic Quartz. By W. H. Charbonnet, Clevite Research Center.

Chemical Raw Materials

Problems of Mining and Exploration of Salt. By L. E. Read and C. H. Jacoby, International Salt Co. Inc.
Lime, the Giant of the Chemical Industry. By R. W. McAllister, Arthur D. Little Inc.
Materials for Nuclear Power. By S. B. Roboff, Sylvania Electric Products Inc.
Ground Disposal of Radioactive Liquid-Waste. By M. I. Goldman, Oak Ridge National Laboratory, and C. P. Straub, Dept. of Health, Education, and Welfare, Cincinnati.
Rutile, an Economic Study. By E. G. Enck, Foote Mineral Co.

Geology of Nonmetallic Mineral Deposits

(Joint Session with Society of Economic Geologists and Geology Subdivision)

General

The Resources and Utilization of North Carolina Pyrophyllite. By J. L. Stuckey, North Carolina Dept. of Conservation and Development.
Processing and Marketing Muscovite Block and Film Mica. By R. D. Thomson, U. S. Bureau of Mines.
New and Old Problems in Refractory Materials. By K. M. Smith, U. S. Bureau of Mines.
Production of Feldspar-Quartz Glass Sand from the Kansas River. By F. W. Bowdish, University of Kansas.
Lightweight Aggregates, Present and Future. By A. R. Rowen, Dwight-Lloyd Div., McDowell Co. Inc.
Opportunities for Research on Utilization and Disposal of Water-Borne Mineral Wastes. By A. A. Berk and B. P. Martinez, U. S. Bureau of Mines.

MINERAL ECONOMICS DIVISION

Economics I

The General Business Outlook. By Charles Broderick, Lehman Bros.
Measurement of Technological Trends in the Mineral Industries. By Paul F. Yopes, U. S. Bureau of Mines.
Measurement of Trends in the Mineral Industry. By John J. Schanz, Jr., Pennsylvania State University.

Economics II

Economic Outlook for Domestic Industries in Strategic Minerals Now Functioning Under Government Assistance.—Government point of view, by Clarence A. Fredell, Materials Div., U. S. Government Emergency Procurement Service, and Jesse C. Johnson, Raw Materials Div., Atomic Energy Commission. Industry point of view, by F. H. Driggs, Fansteel Metallurgical Corp.

Economics III

St. Lawrence Seaway and Mineral Industries. By Raymond F. Stellar, St. Lawrence Seaway Development Corp.
U. S. Markets for Canadian Minerals.—From Canadian point of view, by V. C. Wansbrough, Canadian Metal Mining Assn. From U. S. point of view, by Elmer Pehrson, U. S. Bureau of Mines.
Economic Factors in Cold Weather Operations. By E. B. Spice, Eldorado Mining & Refining Ltd.

Economics IV

Economic Aspects of Atomic Fuels. By Donald Kallman, Babcock & Wilcox.
Determination of Profit Potential of a New Mining Enterprise as a Basis for Attracting Capital. By E. S. Merrill, Standard Research Consultants Inc.
Depreciation Procedures Under Recent Changes in the U. S. Tax Law. By H. B. Fernald, Loomis, Suffern & Fernald.

Pacific Northwest Conference to be Held, Seattle, May 3-5

The 1956 AIME Pacific Northwest Regional Metals and Minerals Conference will be held May 3, 4, and 5 at the Olympic Hotel in Seattle.

Earl R. Marble, recently retired manager of the Tacoma Smelter, American Smelting & Refining Co., is General Chairman of the conference. Working with him in arranging the program that should be of interest to all AIME members who can attend are J. G. Johnston, Bethlehem Pacific Coast Steel Corp., Seattle, Chairman of Metals Branch activities; W. C. Douglas, mining engineer consultant, Seattle, Chairman of Mining Branch activities; and Drury A. Pifer, director, School of Mineral Engineering, University of Washington, Chairman of Mineral Industry Education Div. activities.

Division Chairmen

Subjects listed and the Division Chairmen assisting in preparing them are:

Mining in British Columbia: H. C. Hughes, chief inspector of mines, Dept. of Mines, Victoria, B. C.

Geology: Paul Billingsley, mining geology consultant, Burton, Wash.

Mineral Beneficiation

W. D. Nesbeitt, manager, Spokane District, Allis-Chalmers Mfg. Co., Spokane.

Industrial Minerals: Harold D. Kelley, U. S. Bureau of Mines, Seattle.

Iron and Steel: Lloyd Banning, U. S. Bureau of Mines, Albany, Ore.

Extractive Metallurgy: Robert E. Shinkoskey, manager, Tacoma Smelter, American Smelting & Refining Co., Tacoma, Wash.

Physical Metallurgy: Earl C. Roberts, School of Mineral Engineering, University of Washington, Seattle.

Tours Planned

Plans call for a Mining Branch luncheon, a Metals Branch luncheon, and a grand banquet, as well as tours to metals industry plants in Seattle and Tacoma, and a program of entertainment for the ladies.

Howe Lecturer For 1957 Selected

Edmund S. Davenport, assistant vice president, technical research and technology, U. S. Steel Corp., has been selected to be the Howe Lecturer in 1957, at the Annual Meeting in New Orleans, before the Iron and Steel Div. of the Institute.

Because of the recent death of H. J. French, 1956 Howe Lecturer, John Sands, of the International Nickel Co., will present Mr. French's address. Mr. Sands assisted Mr. French in its preparation.

"Cognate Curricula" Abandoned by ECPD At Toronto Meeting

E. Paul Lange, AIME representative on Engineers Council for Professional Development, reports a successful meeting held in Toronto, Oct. 13 to 14, 1955. Of special interest to the AIME was a decision to abandon the distinction between "Major" and "Cognate" curricula, which caused so much excitement at the last Annual AIME Meeting in Chicago. In "Cognate" were included Ceramic, Geological, Geophysical, and Petroleum Engineering. The Toronto discussion resulted in a decision to place the emphasis on the nature and content of the curricula rather than to the name assigned to a particular group of studies. The institution may call the course by any name it wishes; ECPD will be concerned only with whether or not it is an adequate and satisfactory engineering curriculum. It must assure an adequate foundation in science, humanities, and engineering science, with an introduction to engineering methods, while providing sufficient flexibility in science requirements to accommodate training in special fields. Curricula of a vocational or technical institute pattern cannot qualify, nor can curricula of so specialized a pattern as to provide an inadequate base for engineering at the professional level.

ECPD also voted to sponsor a survey of the engineering profession to include the present and prospective needs for engineering services, the improvement in the utilization of engineers and supporting technical personnel, the scope and nature of the education and training required; the problems of registration, unionization, and ethics involved; and all other matters pertinent to determine the most effective organization of the profession to meet its public responsibilities and professional opportunities.

Fifth Conference Of EUSEC is Held In Denmark

Twenty-six representatives of 15 engineering societies in 12 nations assembled in Copenhagen, Denmark, Sept. 5 to 9, 1955 to participate in the Fifth Conference of Engineering Societies of Western Europe and the U. S. (EUSEC).

The Danish Institution of Civil Engineers acted as host. At the meeting, held in the attractive new buildings of the Institution, President Georg Dithmer served as president of EUSEC and Secretary Ove Guldberg as EUSEC secretary.

The U. S. was represented by President W. R. Glidden and Executive Secretary W. H. Wisely of the American Society of Civil Engineers and President David W. K. Morgan and Secretary C. E. Davies of the American Society of Mechanical Engineers.

Other societies represented were one each from Austria, Belgium, France, Germany, Holland, Norway, Switzerland, Sweden, two from Finland, and the three Institutions of Civil, Mechanical, and Electrical Engineers from the United Kingdom.

Subjects discussed at Copenhagen included a) better means of cooperation between EUSEC and the Pan American Federation of Engineering Societies (UPADI); b) a clarification of engineering organizations within Europe; c) better service for student members; d) uniform definitions of the terms "professional engineer" and "engineering technician"; e) exchange of visiting lecturers; f) formal cooperative agreements between professional societies; g) codes of practice for consulting engineers; h) the responsibility of engineers in conserving natural resources; and i) nuclear-energy discussion forums. These subjects are largely related to the internal operating problems of engineering societies and their discussion resulted in a valuable interchange of experience. Three problems of more general interest were education, engineering manpower, and abstracting.

Engineers Joint Council To Hold Second Assembly

The second annual General Assembly of Engineers Joint Council will be held Thursday and Friday, January 26 to 27, at the Hotel Statler, New York. The problems of utilizing engineering manpower, the growth pattern of the engineer, and the engineering aspects of the Hoover Commission reports are major features of the program. The first day will be devoted to the use of scientific and engineering manpower with respect to Selective Service, the Office of Defense Mobilization, education, and industry. On Friday the topics include problems of engineering education, employers' responsibilities toward the engineer, and the engineer's important place in research and development, with a special look at nuclear power. The meeting will close with a dinner.

Need Money For Research? Apply to Engineering Foundation

Engineering Foundation, a department of United Engineering Trustees, which in turn is a creature of the four Founder Societies—ASCE, AIME, ASME, and AIEE—has some $65,000 annually to distribute for support of research in the engineering field. Currently 27 projects are sponsored. It is not intended that the money allocated in any specific case will cover all the research costs involved, but that it will assist in getting research projects under way that will later be supported by industry. In fact, agreement by Engineering Foundation to sponsor research projects is of real help in getting industrial contributions of much larger amounts.

Of last year's expenditure of $64,650, $25,500 was allocated to projects in the AIME field as follows: Alloys of Iron Research, $5000; Heat Flow in Quenching, $2500; Diffusion in Steel, $2500; Comminution, $3000; Research Council on Corrosion, $1000; Metals Branch, AIME, Publications Fund, $5000; Oscillatory Fluid Motion, $1500; Storm Surges, $5000.

To apply for a grant, write to the Secretary, AIME. The Secretary will turn the request over to the AIME Committee on Research for review and recommendation. If approved the Institute will then recommend it to the Foundation for support. Here is what the application for a grant should cover: a) Benefits expected and the anticipated recipients of the performance, i.e., industries, professions, organizations, or the public. b) Similar, or related, duplicate activities. c) The results, briefly stated, of a search of the applicable literature. If such a search has not been made, the reason should be stated. d) If for continuance of a project already in hand, the application should be accompanied by either a reference to previous periodic reports or a brief statement of work so far done and results obtained. e) Estimates of cost and time, and proposed contributions by the applicant of money and services. f) Information on personnel, facilities, money, and collaboration available from other sources than the Foundation. g) A time schedule for payments when the request is for a grant of money to be expended in a period of one year. h) If a new organization is proposed to execute the undertaking, the reasons therefor and an outline of the proposed organization. Applications for additional grants in any year, or for continuing in succeeding years a project previously aided, should be accompanied by reports of progress or reference to recent progress reports and an outline of the further work planned. Applications should comply with the object of the Foundation, which is the "furtherance of research in science and engineering and the advancement in any other manner of the profession of engineering and the good of mankind."

Application by the Society to the Foundation must be made before April 15 of any year, so immediate application should be made to AIME.

Vote 12 to 1 for New Institute Name

The vote of the membership on changing the name of the AIME to the American Institute of Mining, Metallurgical, and Petroleum Engineers was overwhelmingly in favor of the proposal. Ballots were mailed to 22,864 members. Of these, 12,433 or 54 pct, approved, and 1,026 or 4.5 pct were opposed. On the basis of this vote, the new name will become official at the annual business meeting of the Institute, Feb. 21, 1956. The abbreviation of the name will continue to be AIME, but the emblem—the members' pin—will be redesigned by adding a derrick typical of the petroleum industry to the present crossed hammers.

Student Chapters To Receive Rebate On Dues

As an aid in financing the activities of Student Chapters of the AIME, the Board voted on November 16 to rebate to each Chapter $1 of the $4.50 annual dues paid by each Student Associate member of the Chapter. The plan is effective Jan. 1, 1956. It is believed that the rebate will not only assist in providing more and better Chapter meetings, but will encourage all students to affiliate with their professional society while in college.

The Board also looked favorably on a suggestion that the designation "Student Associate" be changed to "Student Member." Such change, however, would require changes in the bylaws, insignia, and printed matter of the Institute, so the effective date of the change was postponed until other changes can be made at the same time.

1956 Slate of Officers Officially Elected

At the November Board meeting the officers of the AIME for 1956 and six other Directors named to take office for three-year terms in that year were officially declared elected. They are as follows: President-elect, Grover J. Holt; Vice Presidents, J. L. Gillson and Lloyd E. Elkins; Directors, G. F. Moulton, A. Fletcher, C. R. Dodson, C. R. Kuzell, F. J. Meek, and R. B. Caples.

New Calgary Section For Petroleum Members

A new local section has been organized to serve some 100 members of the AIME Petroleum Branch working in the area surrounding Calgary, Alberta. Inasmuch as this area is in the province of the Canadian Institute of Mining and Metallurgy, which has a Petroleum Division, arrangements completely agreeable to the CIM were developed. The new Section will be known as the CIM-AIME Petroleum Engineering Section of the CIM. However, the Petroleum Branch of AIME will assist its operation in every way possible, the Section will be given a rebate of 50¢ for each AIME member on its rolls, and a Section delegate will be allowed on the Council of Section Delegates. In addition, each member of the new Section who is a member of the CIM but not of the AIME will be offered a subscription to the JOURNAL OF PETROLEUM TECHNOLOGY at the special AIME members' rate of $4 per year, half the regular subscription price.

How to Get a Free AIME Pin

AIME members who secure at least five new members now get tangible recognition for their efforts. This is in the form of the well known emblem, AIME with crossed hammers in gold on a blue background, surrounded by a band of white on which is inscribed Membership Award. Dangling from the bottom of the pin is a small light blue pendant with the figure 5. When the member gets five more members he gets another pin with a pendant bearing the figure 10, thus having a pin for each suit, and so forth. Up to December 7, 34 pins had been issued for five members; 9 for ten; 2 for fifteen; and 1 for twenty. Application blanks now have a space at the top on which the man who secures the application writes his name when passing out the application. This makes it possible to keep a tally at AIME headquarters.

AAAS Fellowships

The American Assn. for the Advancement of Science has redefined its fellowship qualifications and AIME is now on the list of organizations that have a research qualification for membership. Members are eligible for AAAS fellowship if they belong to the association or join it.

Of the two principal classes of members in the association, Fellows are those who have contributed to the advancement of science either by the publication of original research beyond the doctorate thesis or in other significant manner.

CHANGE IN NOMINATING COMMITTEE FOR 1957 OFFICERS

H. Carroll Weed has been appointed to succeed P. D. I. Honeyman as Alternate for T. G. Chapman.

Further Progress Report By the Long-Range Planning Committee

Andrew Fletcher, Chairman, Leo F. Reinartz, and Carl E. Reistle, Jr., comprising the Special Committee on Long-Range Planning, presented a third progress report at the November 16 Board meeting. Because of the variance of expressed views it was recommended that an outside consultant make an objective study of the Institute and its problems, and for this job, Norman Mitchell, of A. T. Kearney & Co., Chicago, was suggested. He had worked with the Johnson Committee on a report on the internal organization of the Institute eight years ago.

New Student Chapter At Texas A & M

A new Student Chapter of the AIME has been recognized, the Geology Club of the A & M College of Texas, College Station. The school has ECPD accredited curricula in Geological and Petroleum Engineering. Paul Weaver is Faculty Sponsor.

Volume on Mineral Economics Is Financed

In the planning stage for the last two or three years, the special volume on mineral economics, by the Mineral Economics Div., has now been financed through establishment of an underwriting fund supplied by Henry T. Mudd, his mother, and sister. The volume will be a memorial to Harvey S. Mudd and will be one of the Seeley W. Mudd Series. Contents of the various chapters have already been tentatively set, authors will be selected immediately, and the actual writing and editing should be completed in the coming year. Edward H. Robie has agreed to act as editor-in-chief of the volume.

AIME to Sponsor "Acta Metallurgica"

Acting on a request from the board of directors of *Acta Metallurgica*, the recently launched magazine devoted to metal physics, the AIME Board has voted to become a "Sponsoring Society" by financially supporting the enterprise. One fifth of the annual deficit of *Acta* will be met by the AIME, but not to exceed $2000, half of which is to be taken from one of the endowed funds of the AIME and half from the private funds of the Institute of Metals Div. It was felt that the AIME prestige in this field would thus be enhanced and that there would be no competition with the JOURNAL OF METALS.

Krumb Scholars To Meet for Banquet

Krumb Scholars from all parts of the U. S. will gather at Columbia University Club in New York for a banquet, Feb. 18, 1956. Each year Krumb Scholars at Columbia University School of Mines have held a banquet in honor of Henry Krumb, the well known engineer and an 1898 graduate. His scholarship fund grants yearly scholarships of $1000 each. This year Mr. Krumb has requested that all Krumb Scholars—past and present—be his guests. Notices have been sent to some 45 Krumb Scholars and a large turnout is expected.

New College to Bear Name of Harvey S. Mudd

A new college of liberal arts emphasizing basic science and engineering will bear the name of the late Harvey Seeley Mudd, Los Angeles mining engineer and civic leader. This college will be established at Claremont, Calif., William W. Clary, chairman of the Board of Fellows of Claremont College, has announced.

For three decades prior to his death in April 1955, Mr. Mudd was active in the development of the group plan of colleges at Claremont, having served as chairman of the board of Claremont College, central coordinating institution, for 18 years and as a trustee for 29 years. Mr. Mudd's father was that board's first chairman. Mrs. Harvey Mudd is a trustee of Claremont College, as is their son, Henry T. Mudd, who also serves on the board of Claremont Men's College.

Harvey Mudd is remembered in Southern California for his activities in many fields. He was the principal founder of the Southern California Symphony Assn., was a director of the Hospital of the Good Samaritan, a member of the Advisory Board of the Huntington Library, head of the Los Angeles War Chest in 1943 and campaign manager of the Community Chest in 1947.

As a mining engineer, Mr. Mudd received many awards and was a Director, Vice President, and President (1945) of the AIME. In 1948 he was awarded the Egleston Medal of Columbia University.

Puget Sound Student Chapter Suspends

Announcement has been made that the AIME Student Chapter at the College of Puget Sound, Tacoma, Wash., has been discontinued at the Chapter's request. The school has no ECPD accredited curricula in the mineral technology field.

Around the Sections

• The **St. Louis Section** met November 18 at the Hotel York. A. W. Schlechten, Vice Chairman, was presiding officer, and 71 were there, including students from Missouri School of Mines. C. K. Bain, consulting mining engineer, spoke on "A Coordinated and Mechanized Shaft Sinking Method." No temporary shaft is used with this method. There is permanent ventilation and air and discharge lines are set in concrete lining rather than left hanging in the shaft. The aim, Mr. Bain said, was safety rather than speed. He illustrated his talk with many colored slides.

N. L. Shepard, Chairman of the Nominating Committee for officers for 1956, reported on nominations as follows: A. W. Schlechten, Chairman; C. H. Cotterill, Vice Chairman; G. M. Bell, Secretary-Treasurer.

• The **Utah Section** met December 8 to hear a Panel Discussion of the Columbia-Geneva Div., U. S. Steel Corp. W. T. Purvance, works engineer, was moderator. Members of the Panel were: Myron Strate, assistant division superintendent of maintenance and utilities, R. D. Hayes, engineer, and P. T. Cropper, supervisor of safety. Subjects discussed during the evening were: "Prefabrication and Move in for Open Hearth Furnaces," "The New Anhydrous Ammonia Plant," and "Overall Safety at Geneva Plant."

• The **Florida Section** met December 9 at Brewster, Fla. Following a buffet supper and a business session, members saw the film *Resources for Freedom*.

• The **Washington, D. C., Section** met December 6 at the Cosmos Club to hear John J. Forbes. Mr. Forbes, director, U. S. Bureau of Mines, is retiring after 41 years of service. He annotated the significant contributions that the USBM has made to national welfare since the Bureau was established in 1910. Section officers for 1956 are: Clarence A. Fredell, Chairman; H. I. Smith, Vice Chairman for the District of Columbia; C. J. Williamson, Vice Chairman for Maryland; Rafford Faulkner, Vice Chairman for Virginia; John E. Holtzinger, Jr., Secretary-Treasurer. Members of the Executive Committee are George P. Holderer and Ralph Miller.

• H. DeWitt Smith, AIME President, discussed Institute policies and plans at the **New York Section** meeting, December 8. He also awarded a Legion of Honor pin and certificate to Henry Krumb. Mr. Krumb is a former Vice President and Director of AIME. The meeting was held at the Mining Club and J. H. Ffolliott was Chairman.

• The annual dinner meeting of the **Lehigh Valley Section** was held December 2 in Bethlehem, Pa. Ernest G. Enck presented "To the Land of Zulus." Mr. Enck is secretary and director of procurement, Foote Mineral Co., Philadelphia. Section officers elected were: D. S. Lyons, Chairman for one year; R. M. Johnson, Vice Chairman for one year; W. M. McKewan, Vice Chairman for three years; and C. G. Tebelman, manager for three years. An afternoon tour of the plant of Bethlehem Steel Co. preceded the evening at the Hotel Bethlehem.

• On December 10 the **El Paso Metals Section**, the Woman's Auxiliary, and their guests met for a Christmas Party. It was held at the El Paso Club of the Hotel Cortez with cocktails, dinner, and dancing. There were many complaints that the evening was over too soon!

• The **Boston Section** met November 17 at the MIT Faculty Club. J. B. Metcalfe was chairman and 50 attended. Richard S. Morse, president of National Research Corp., spoke on "Recent Advances in Vacuum Metallurgy." The December 5 meeting speaker was Paul Queneau, his topic "Extractive Metallurgy at Inco." Mr. Queneau is assistant to the vice president, International Nickel Co. of Canada Ltd.

• The **Reno, Nev., Subsection** met November 18 at El Cortez Hotel. John W. Kenney, Jr., manager, Eagle-Picher diatomite plant, Clark Station, Nev., was speaker. He discussed diatomaceous earth and its products, their applications, and various aspects of mining and processing. Revised bylaws for the Subsection were approved and the idea of revolving technical meetings in the Pacific Southwest was favorably received. This is to be reviewed on the State Section level before further action.

• The **Chicago Section** meeting December 7 was held at the Chicago Bar Assn. and ladies were invited. Harold C. Urey chose for his subject the "Composition of the Earth and Meteorites, and the Abundance of the Elements." Professor Urey is with the Institute for Nuclear Studies, University of Chicago. He is the recipient of ten major awards including the Nobel Prize in chemistry.

• The **Lima, Peru, Section** met November 16 at the American Room in the Hotel Bolivar. Enrique Trujillo Bravo, director, Aguas e Irrigación, Ministerio de Fomento, spoke on "Irrigation in Piura." Following this, two short films were shown on atomic energy for peace—*"A" is for Atom* and *The Atom and Industry*.

• The **Southwestern New Mexico Section** held a technical session last October in the Bayard Lions Club Bldg. Chairman E. A. Slover presided with 35 members present. Will W. Baltosser, chief mine engineer, Chino mine, and Bernard C. Jacobs, concentrator metallurgical engineer, Chino mill, spoke on the treatment of sliming ores at Chino's concentrator. Mr. Baltosser discussed the character and occurrence of these ores in the Santa Rita pit. It is impossible to mine them in uniform daily amounts.

• Twenty-two members of the **Black Hills Section** met in Rapid City, S. D., November 9 at South Dakota School of Mines and Technology. Edwin H. Oshier presented a colored slide travelogue of old and new mining districts of the Southwest, West, and the Colorado Plateau. Mr. Oshier is professor of mining at the School of Mines. Section officers elected for 1956 are: William C. Campbell, Chairman; Alexander E. McHugh, 1st Vice Chairman; Edward H. Stevens, 2nd Vice Chairman; Ted M. Rizzi, Secretary-Treasurer. Members of the Executive Committee are: Renaldo D. Gallo, who was formerly Section Chairman, Langan W. Swent, Claude E. Schmidt, F. L. Partlo, and Paul H. Anderson. Edward H. Stevens is Section Delegate.

• The final 1955 meeting of the **Eastern North Carolina Subsection** was held in Henderson, N. C., at the Hotel Vance December 3. Speaker for the evening was Philip Eckman of Appalachian Sulphides Inc., Jefferson, N. C. His topic was "Ore Knob—North Carolina's New Copper Mine."

• ***To Enrich Mankind*** **is the title of a 25-min color motion picture released by the American Society of Mechanical Engineers. Believed to be the first such production ever sponsored by one of the major engineering societies, the film is designed to explain to the public the significance of the role mechanical engineering plays in the development of the U. S.**

The film is in 16-mm Eastman color and prints are available on loan without charge to schools, television stations, and nonprofit organizations by writing to Barbara A. Brown, Public Relations Dept., ASME, 29 W. 39th St., New York 18, N. Y.

PERSONALS

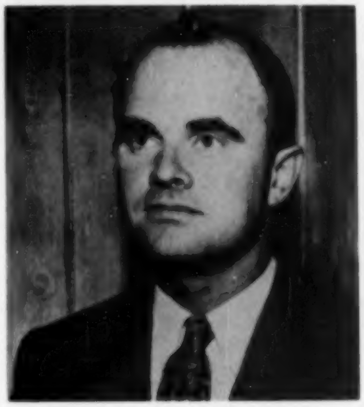
Kenneth A. Spencer, president, Pittsburg & Midway Coal Mining Co. and Spencer Chemical Co., Kansas City, represented the bituminous coal industry before The Panel on the Impact of the Peaceful uses of Atomic Energy, which met on October 31 and November 1. Mr. Spencer is chairman of the Atomic Energy Committee of National Coal Assn. and also a director of the association.

B. C. Lansing, assistant pit superintendent, Ray Mines Div., Kennecott Copper Corp., Ray, Ariz., has been named general manager of the Tin & Associated Minerals Ltd., columbium property in western Nigeria. Mr. Lansing has been with Kennecott for 15 years. During the academic year 1950 to 1951 he was the recipient of the Kennecott scholarship in mining engineering at the University of Arizona. Mr. Lansing joined the Ray Mines Div. in 1951 as a level boss in the engineering dept. **Ray W. Ballmer,** mine industrial engineer for the open pit mine at Ray, succeeds Mr. Lansing as assistant pit superintendent. Mr. Ballmer joined Kennecott in 1944 after graduating from New Mexico School of Mines. He was employed as a miner and engineer at Magdalena and Socorro, N. M., while working toward his engineering degree.

Lawrence K. Marshall is production superintendent, E. M. M. Co., Bukit Besi, Dungun Trengganu, Malaya.

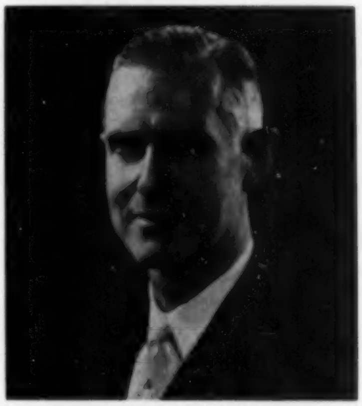
J. P. Caulfield, general manager, Western Mining Divisions, Kennecott Copper Corp., Salt Lake City, has been appointed assistant to the vice president in the company's executive offices, New York. **C. D. Michaelson,** vice president and chief executive in Chile of the Braden Copper Co., a subsidiary of Kennecott, will become general manager, Western Mining Divisions, Salt Lake City. **R. M. Haldeman,** general manager, Braden Copper Co., will become the chief executive for Braden in Chile. Mr. Caulfield became associated with Kennecott in 1951 as general manager of the Utah Copper Div. He is a 1923 graduate of the University of Utah with a B.S. in mining engineering and mechanical engineering. He was awarded an E.M. by the university in 1930. Mr. Michaelson joined Braden Copper Co. as general superintendent in 1948. He is a 1932 graduate of Colorado School of Mines. Mr. Haldeman was employed by Braden Copper Co. as shift boss and level foreman in 1941 and became general manager in 1954. He is a 1939 graduate of the University of California.

F. C. Menk has been appointed engineering consultant to the vice president of operations, Island Creek Coal Co., Holden, W. Va. Mr. Menk joined Island Creek in 1921 as a draftsman and became director of engineering in 1949.



THOMAS M. WARE

Thomas M. Ware, vice president in charge of engineering, International Minerals & Chemical Corp., Chicago, has been elected to the newly created office of administrative vice president. In his new position Mr. Ware will be responsible for engineering, purchasing, traffic, marketing, and mining and minerals exploration. He has been with International for eight years. During World War II he served as a project engineer in the Navy. Mr. Ware graduated from Cornell University in 1940 with an engineering degree. **Nelson C. White,** general manager of the Potash Div., has been elected vice president in charge of that division. Mr. White is a chemical engineer with 27 years of experience in the chemical industry. He has been with International since 1942. Mr. White succeeds **A. Norman Into** who recently resigned.



NELSON C. WHITE

C. W. Neikirk has resigned as vice president and general manager of Blue Rock Inc., Washington Court House, Ohio. Mr. Neikirk is now sales representative for Independent Explosives Co., Cleveland, and will be located at Washington Court House.

Fred A. Miller is sales engineer for Industrial Equipment & Engineering Corp., Miami, Fla. Mr. Miller was formerly superintendent, CW & F Orient mine No. 3, Chicago, Wilmington & Franklin Coal Co., Waltonville, Ill.

Robert L. Squires is geologist, Western Gold & Uranium Inc., Leeds, Utah. Mr. Squires was formerly with Cyprus Mines Corp., Tucson, Ariz.

Ralph J. Long is project manager, Ozark Philpott mine, a division of Utah Construction Co. in Arkansas. Mr. Long was drilling and blasting superintendent, Shen Penn Production Co. in Pennsylvania.

Vernon S. Severtson has been appointed superintendent, No. 1 Board Plant, U. S. Gypsum Co., Sweetwater, Texas. Prior to joining U. S. Gypsum in 1954, Mr. Severtson was a field engineer for the Eimco Corp., Chicago.

Vernon T. Dow has joined the staff of Norbute Corp. as manager of the Ringtail uranium mine, Colorado. For the past four years Mr. Dow has been chief engineer, Colorado Exploration Project in Uranium, U. S. Geological Survey, Grand Junction. Before joining the USGS he was associated with Miami Copper Co., Kennecott Copper Corp., and Sunshine Mining Co. **Abbott Charles** has also joined Norbute Corp. and will manage the Western Mining Div. Mr. Charles is a consulting engineer of Oakland, Calif. He spent three years with the Union Mines Development Corp., which was under contract with the Manhattan Project during World War II for mapping uranium resources of the Colorado Plateau.

Richard C. Cole, plant manager, Vitro Uranium Corp., Salt Lake City, has been named assistant general manager. Mr. Cole will also continue as plant manager. Prior to joining Vitro Uranium Co. last year, Mr. Cole had been associated for 20 years with American Smelting & Refining Co. at Tacoma, Salt Lake City, and New York. Mr. Cole is a graduate of the University of Washington, Seattle.

Robert Dale Greer is now application engineer, Joy Mfg. Co., Franklin, Pa. Mr. Greer was formerly assistant mine superintendent, Inland Steel Co., Wheelwright, Ky.

Thomas H. Lentz has joined the Bureau of Mineral Research, Michigan College of Mining and Technology, Houghton, as a research engineer. Mr. Lentz was an associate chemical engineer at General Mills Inc., Minneapolis.

John R. Mullen has accepted a position as mine superintendent at the Rajah shaft, Beaver Mesa Uranium Co., Grand Junction, Colo. Mr. Mullen was with the American Chrome Co., Nye, Mont.

H. J. MAYER

B. C. Jacobs has been named general mill foreman, Kennecott Copper Corp., Chino Mines Div., Hurley, N. M. Mr. Jacobs joined Chino in 1938 as an assayer at the Hurley mill. Prior to that he was a chemist and research engineer with The Anaconda Co. **Paul Lemke** succeeds Mr. Jacobs as metallurgical engineer at the mill. Mr. Lemke started to work for Chino in 1939 in the assay office. In 1948 he was named chief research chemist and in 1953 was promoted to flotation foreman.

John F. Dugan has been recalled by The Anaconda Co. to serve as consulting engineer for recruitment and personnel. Mr. Dugan retired several months ago as general superintendent of mines, International Smelting & Refining Co., an Anaconda subsidiary in Salt Lake City.

Luis A. Jáuregui has joined Lance Engineering Co., El Paso, Texas, as mining engineer and will do mine examination, exploration, and mine and mill plant design. Mr. Jáuregui was mine foreman, Fresnillo Co., Naica, Chihuahua, Mexico.

Jack E. Nelson is mill chief, The New Jersey Zinc Co., Jefferson City, Tenn. Mr. Nelson was with the company's Empire Zinc Div., in Gilman, Colo., for eight years.

Jack H. How, president, Western Machinery Co., San Francisco, has announced the following executive appointments: **H. J. Mayer,** who has been with WEMCO for 20 years, is executive vice president. **C. F. Skinner,** a long-time associate who has traveled extensively for WEMCO, is general manager of manufacturing, engineering, and construction. **R. B. Utt,** one of the leaders in the development of new units of equipment, is chief executive engineer. **W. H. Newton,** a relative newcomer to WEMCO, is general sales manager for WEMCO products and Western Knapp Engineering services.

Leland H. Johnson, chief engineer, Tennessee Coal & Iron Div., U. S. Steel Corp., Bessemer, Ala., has been named assistant general superintendent. **Lucien S. Chabot, Jr.,** formerly works industrial superintendent, will succeed Mr. Johnson as chief engineer.

Raymond W. Jenkins is project superintendent, National Potash Co., Carlsbad, N. M. Mr. Jenkins was formerly field engineer, Freeport Sulphur Co., Carlsbad.

Hollis M. Dole is director, Oregon State Dept. of Geology and Mineral Industries, Portland. Mr. Dole has been with the department since 1946 and was made acting director in November 1954. He graduated from Oregon State College with a B.S. and M.S. and completed scholastic requirements for a doctorate degree at the University of Utah.

Emmett B. Ball, Jr., is field engineer, Victorville Lime Rock Co., in California. Mr. Ball was with Kaiser Steel Corp., Eagle Mountain, Calif., for four years.

Helmut Leidhold has joined Sociedad Minera Argentina S.A., Concarán, Province of San Luis, Argentina, and is now efficiency engineer at Los Cóndores mine. Mr. Leidhold was formerly with Consorcio Industrial Minero, La Ramadita, Catamarca, Argentina.

C. F. SKINNER

Thomas L. Kesler, chief geologist, Foote Mineral Co., Kings Mountain, N. C., recently returned from the third of a series of trips to the lithium-ore districts of Canada. These districts include parts of Quebec, Ontario, Manitoba, and Northwest Territories.

Roger J. Howell is safety director, Kennecott Copper Corp., Nevada Mines Div., Ruth, Nev.

Wayne O. MacKenzie has left the geological field to go into full-time ministerial work.

E. K. Miller is planning to open an office as a consultant in the Grant Building, Pittsburgh. Mr. Miller recently left Jones & Laughlin Steel Corp., after 26 years of service. During that time he held many positions in the company, including that of vice president, operations. Mr. Miller started in the steel industry in 1911 with the Carnegie Steel Co. He was chairman of the Blast Furnace, Coke Oven, and Raw Materials Committee of the Iron and Steel Div. of the AIME, and also vice chairman of that division for 1951 to 1952.

Emery H. Nielsen is district manager, Dowell Inc., Denver. Mr. Nielsen was general sales engineer for the company at Tulsa, Okla.

Roy G. Stott has been promoted to subdistrict supervisor, Health and Safety District A, U. S. Bureau of Mines, Albany. Mr. Stott was formerly with the Duluth field office.

Andrew V. Bailey is now mining development and production engineer, U. S. Geological Survey, Miami, Okla. Mr. Bailey was with Woodward Iron Co., Woodward, Ala.

Roy F. Gray has accepted a position as mill superintendent, Mt. Morgan Ltd., Queensland, Australia. Mr. Gray was formerly assistant mill superintendent, Rhokana Corp. Ltd., Kitwe, Northern Rhodesia.

Roy K. Alexander, resident sales engineer, Gardner-Denver Co., has been transferred from Minneapolis to Buenos Aires, Argentina.

Alexander C. Brown, chairman of the board, Cleveland-Cliffs Iron Co., Cleveland, has relinquished his duties as chief executive officer to **Walter A. Sterling,** president, Cleveland-Cliffs. Mr. Sterling started with the company in 1929 as a mining superintendent. He became manager of Minnesota mines in 1949, vice president in charge of mining operations in 1950, and president in 1953. Mr. Sterling is a graduate of the University of Michigan.

Joseph J. Yancik is now employed as research engineer by St. Joseph Lead Co., Bonne Terre, Mo. Mr. Yancik recently completed the requirements for a master's degree in mining engineering at the Missouri School of Mines, Rolla.

J. E. Douglas has been appointed district sales manager, Joy Mfg. Co., El Paso, Texas. He succeeds **E. E. Miller,** who has retired after 43 years' service with the company, including several years overseas with Joy's export dept.

George W. Pendell is now employed in the Mexican mining dept., American Smelting & Refining Co., El Paso, Texas. Mr. Pendell was with the Denver Fire Clay Co., El Paso.

Richard Elliott Wainerdi is at Oak Ridge School of Reactor Technology, Oak Ridge, Tenn. Mr. Wainerdi was formerly a research fellow at Pennsylvania State University, petroleum and natural gas dept.

Rollin A. Pallanch is available as consultant in milling, mineral beneficiation, and metallurgical work at 1654 Millbrook Rd., Salt Lake City 6. Mr. Pallanch recently retired from his position as consulting mill metallurgist with U. S. Smelting Refining & Mining Co., Salt Lake City. He is a graduate of the University of Wisconsin.

C. J. Nelson, mining engineer of Panama City, Fla., has gone to Saudi Arabia for Bechtel International Inc.

Ralph H. King, consulting geologist, Lawrence, Kan., has accepted the position of technical editor for the State Geological Survey, University of Kansas. Since 1952 he has been an instructor in paleontology and a research geologist at the University of Kansas. Mr. King was State Geological Survey editor from 1939 to 1941. In 1934 he was awarded a Geological Society of America grant to study the paleontology and stratigraphy of Permian and Pennsylvanian rocks in north-central Texas.

James V. Reynolds, president, Joplin Machinery & Electric Co., is now at the company's new offices in Albuquerque, N. M. Mr. Reynolds is also president of Century Lead & Zinc Co. He is a former director of Tri-State Lead & Zinc Ore Producers Assn.

SOLOMON LIEB

Solomon Lieb has left the Corporación Minera de Bolivia, La Paz, Bolivia, and is now in New York. Mr. Lieb was metallurgical ore dressing consultant and general superintendent of all mills and laboratories for the corporation.

Robert E. Smith is geological engineer, Schlumberger Well Surveying Corp., Kermit, Texas. Mr. Smith was formerly with Miami Copper Co., Miami, Ariz.

J. C. C. Blair, Jr., has been appointed general field superintendent, E. J. Longyear Co., with headquarters in Minneapolis. Mr. Blair joined the Longyear Co. in 1939 and has served successively as drill helper, driller foreman, and field superintendent for the eastern U. S. During World War II he was in the Navy.

A. L. Hodge, research metallurgist, Linde Air Products, is now at the development laboratory, Newark, N. J. Mr. Hodge was in the research laboratory, Tonawanda, N. Y.

Glen B. Wilson, pit shift foreman, Ray Mines Div., Kennecott Copper Corp., Ray, Ariz., has been promoted to drilling and blasting foreman. Prior to joining Kennecott in 1949, Mr. Wilson was mine superintendent of the Crown Point Mining Co., Globe, Ariz. He is a graduate of Washington Stage College.

Jack D. Stavropodis is now a professor, natural science dept., Athens College, Athens, Greece. Mr. Stavropodis was with the Greek Geological Survey in Athens.

Woodward J. Latvala has been promoted to mine superintendent, Consolidated Coppermines Corp., Kimberly, Nev. He was assistant chief engineer. Prior to joining Consolidated Coppermines Corp., Mr. Latvala was superintendent of open pit mining for Reynolds Jamaica Mines Ltd. in Jamaica. He is a graduate of the New Mexico School of Mines and in 1950 received an M.S. from Missouri School of Mines and Metallurgy, Rolla, Mo.

R. N. Whisenant has been promoted to special representative, Hercules Powder Co., Pittsburgh. Mr. Whisenant was formerly technical serviceman for the company in Salt Lake City.

John W. Harshbarger is district geologist, Arizona District, Ground Water Branch, U. S. Geological Survey, Tucson, Ariz. Mr. Harshbarger has been transferred to Tucson from Holbrook, Ariz.

Spencer S. Shannon, Jr., is geologist, U. S. Atomic Energy Commission, Rawlins, Wyo. Mr. Shannon was formerly commodity industry analyst, U. S. Bureau of Mines, Washington, D. C.

Henry E. Mensing is now mine foreman, National Gypsum Co., Bellefonte mine, Pa. Mr. Mensing was formerly mine engineer.

Joseph B. Perry, chief mining engineer for the Chemical Divisions of Food Machinery & Chemical Corp., Newark, Calif., has retired from full-time active duty after 35 years of service. Mr. Perry will continue with the company on a consulting basis. In 1920 Mr. Perry joined the Sierra Magnesite Co., which was later acquired by Westvaco Chemical Corp., as chief mining engineer. He subsequently served in a similar capacity for the Westvaco Chemical Corp., and for the past several years has been chief mining engineer for the Chemical Divisions of Food Machinery & Chemical Corp. A testimonial dinner was given in his honor at Palo Alto, Calif., in October. **M. Y. Seaton,** corporate vice president and technical coordinator of the Chemical Divisions, was master of ceremonies.

William K. Bowie is assistant mining engineer, Colorado Fuel & Iron Corp., Trinidad, Colo.

Richard D. Ellett, geologist, National Lead Co., Grand Junction, Colo., was recently in Argentina examining mineral deposits.

JAMES E. CASTLE

James E. Castle has been appointed manager, Industrial Minerals Div., International Minerals & Chemical Corp., with headquarters in Chicago. Mr. Castle was plant manager, Foote Mineral Co., Kings Mountain, N. C. He has had extensive mining experience in the U. S. and abroad.

Richard C. Klugescheid, vice president, Kennecott Copper Corp., New York, has been retired under the company's retirement plan.

Charles J. Ayres is engineer, Austin & Smith Operators, Altoona Mines, San Francisco. Mr. Ayres was formerly superintendent, Yellow Jacket Consolidated Gold Mines Ltd., Bakersfield, Calif.

E. R. Packer, formerly general superintendent, Argentum Mining Co., Mina, Nev., is now with Cía. Inspiración Cubana de Cobre, Barajagua, Las Villas, Cuba.

E. P. Pearson has been appointed assistant technical director, Basic Refractories Inc., Cleveland. Mr. Pearson joined the company in 1942. Prior to that time he had been associated with American Potash & Chemical Corp., Trona, Calif. Mr. Pearson holds B.S. and M.S. degrees from the University of Wyoming.

William R. Atkins is mine superintendent, Kimballton plant, National Gypsum Co., Kimballton, Va. Mr. Atkins was formerly superintendent, Negaunee mine, Cleveland-Cliffs Iron Co., Negaunee, Mich.

Thomas V. Barton, Jr., sales engineer, Dorr-Oliver Inc., Western Filtration Div., Oakland, Calif., has been transferred to the Eastern Filtration Div., Stamford, Conn. Mr. Barton joined Dorr-Oliver in 1954 and has served successively as a sales and service engineer in the Eastern Filtration Div., and as a sales engineer in the Western Filtration Div. He received a B.S. in mining engineering from the Mackay School of Mines, University of Nevada, in 1951.

Arthur Blake Caldwell is assistant sales engineer, American Cyanamid Co., New York. Mr. Caldwell was quarry superintendent, U. S. Gypsum Co., Farnams, Mass.

T. H. McClelland has been appointed general manager of Pato Consolidated Gold Dredging Ltd., and of Asnazu Gold Dredging Ltd., Vancouver, B. C. Mr. McClelland is also a director of the two companies and of Consolidated Purchasing & Designing Inc., American Exploration & Mining Co., Bulolo Gold Dredging Ltd., and Coronet Oil Co. He succeeds **R. E. Franklin** who has retired.

J. M. Bracken is mine superintendent, Consolidated Denison Mines Ltd., Blind River, Ont. Mr. Bracken was assistant manager, Dominion Wabana Ores Ltd., Bell Island, Newfoundland.

Guerdon E. Jackson is now resident mining engineer, Arizona operations, Thornburg Bros., Grand Junction, Colo. Mr. Jackson was mine superintendent, Golden Crown Mining Co., Grand Canyon, Ariz.

R. W. Gerling is assistant to the president, New Idria Mining & Chemical Co., Idria, Calif. Mr. Gerling was formerly superintendent, Empresas Mineras, Lima, Peru.

Robert L. Kovach is Stanolind Oil & Gas Co. Fellow in Geophysics at Lamont Geological Observatory, Columbia University. Mr. Kovach graduated from Colorado School of Mines in 1955.

C. I. Gardner is now with the Atomic Energy Commission, Div. of Raw Materials, Washington, D. C. Mr. Gardner was with the AEC, Exploration Div., Grand Junction, Colo.

Allen D. Kennedy is now research engineer and assistant director, Michigan Bureau of Mineral Research, Houghton. Mr. Kennedy was metallurgist in charge of flotation and milling research, Tennessee Copper Co., Copperhill, Tenn.

A. H. MILLER

Arnold H. Miller, consulting engineer, New York, has gone to Europe. Mr. Miller will examine mines in Spain, France, and North Africa.

Daniel C. Shewmon has been promoted to industrial engineer, Semet-Solvay Div., Allied Chemical & Dye Corp., Tralee, W. Va. Mr. Shewmon was plant engineer, Tralee colliery.

James H. Eastman is field engineer, Pato Consolidated Gold Dredging Ltd., Barranquilla, Colombia.

Charles C. Towle, formerly chief, Denver Exploration Branch, Div. of Raw Materials, Atomic Energy Commission, has joined The American Metal Co. Ltd., Denver. Mr. Towle will be in charge of Western exploration activities.

Howard I. Young, president, American Zinc, Lead & Smelting Co., St. Louis, has announced that the company is establishing headquarters for the Western operations of the parent company and its subsidiaries at Salt Lake City. The Salt Lake City staff will also act as Western concentrate purchasing dept. The office will be under the management of **R. E. Calhoun,** Western manager. Mr. Calhoun joined the American Zinc organization in 1926 after graduating from North Georgia Agricultural College. Since 1950 he has been Southwestern representative of the company with headquarters at El Paso, Texas. **Hiram F. Mills,** chief Western geologist, will also make his headquarters at Salt Lake City. Mr. Mills joined the American Zinc organization in 1927 after graduating from Harvard University where he majored in geology. He has held his present position since 1951 and in that capacity has visited various parts of the U. S., Latin America, Newfoundland, and Africa.

Mr. Young has also announced the following changes in the organization: **Howard Lee Young,** vice president, American Zinc Sales Co., a subsidiary of American Zinc, Lead & Smelting Co., has been elected a vice president of the parent company. **William J. Matthews, Jr.,** is vice president and treasurer. Mr. Matthews has been connected with the company for 39 years. **Clarence V. Burns** is vice president and controller. Mr. Burns joined the company's mining operations at Niehart, Mont., in 1923. **Ralph C. Perkins** is secretary. Mr. Perkins will also continue his duties as chief counsel of the company.

Arthur P. Cortelyou is mining consultant, Union Carbide Nuclear Co., New York. Mr. Cortelyou was general manager, U. S. Vanadium Co., New York.

D. R. de Vletter resigned from the Nickel Processing Corp., Nicaro, Oriente, Cuba, last October. After a short stay in Holland Mr. de Vletter joined the geological staff of International Nickel Co. of Canada, Copper Cliff, Ont.

Frank J. Canales is now connected with New York & Honduras Rosario Mining Co., Honduras. Mr. Canales was formerly mill superintendent, Minas Montecristo Inc., Divisadero, El Salvador.

Dale I. Hayes, formerly Western manager for American Zinc, Lead & Smelting Co. has been appointed assistant to the president, with headquarters at Knoxville, Tenn. **John W. Currie,** general superintendent, Grandview mine, Metaline Falls, Wash., is being promoted to resident manager and **Ewald A. Frick** is promoted to assistant resident manager at the same property.

M. F. DUFOUR

Maurice F. Dufour has been elected vice president of Nicaro Nickel Co., a subsidiary of Freeport Sulphur Co., New York. Mr. Dufour, who has been associated with Freeport or subsidiary companies in technical and executive capacities since 1933, will be in charge of the company's project to develop nickel and cobalt orebodies at Moa Bay on the northeastern coast of Cuba. Mr. Dufour joined Freeport as a laboratory assistant at its Texas sulphur operations. After filling various positions he was elected assistant vice president in 1954.

OBITUARIES

William H. Burgin
An Appreciation by
Sheldon P. Wimpfen

When a United Airlines plane on a Denver to Salt Lake City flight crashed into Medicine Bow Mountain on Oct. 6, 1955 it took with it 66 souls. Among them was William H. Burgin (Member 1939), a mining engineer and geologist well known in his field. The crash cut short a career which promised much in the future development of this nation's mineral resources. At the time of his death, Bill was in charge of Rocky Mountain region exploration activities conducted by Bear Creek Mining Co., Kennecott's exploration arm.

In his last professional position, Bill was with the company which employed him at the start of his career in the mineral industries field. He was born in Springfield, Mo., on Apr. 23, 1918. After being graduated in 1940 from the Missouri School of Mines and Metallurgy in Rolla, Mo., with a B.S. degree in mining engineering, he worked in Kennecott's Bingham Pit. There, as a trainee, he spent two months working in the pit as track gang laborer and shovel oiler, then 20 months in all of the various operating departments in the Magna mill as either helper or operator, leaving Kennecott to join the armed services.

While waiting for his call to join the U. S. Air Force after the beginning of World War II he was supervising construction of facilities connected with a Naval Training Station in Maryland. Upon completion of his cadet training at Yale University he served both in the U. S. and Europe in various engineering officer posts and was responsible for the maintenance of large numbers of B-17 and B-24 bombers of the 493rd and 453rd Bomb Groups of the 8th Air Force. Here he received the Bronze Star decoration for services during the heavy bombing of Germany.

When the war came to an end, Bill became affiliated with Mines Inc., a subsidiary of Ventures Ltd. of Canada, for whom he supervised the exploration of a potential large open pit gold property in the Cripple Creek, Colo., area, where he designed and operated a bulk sampling plant to develop a basis on which full-scale operations might be predicated at such time as economics might permit. With that task completed, he undertook the exploration and development of a long abandoned lead-silver mine near Westcliffe, Colo., for Pacific Bridge Co. and then supervised the exploration and development of extensive tailings deposits accumulated from prior operations in the Park City, Utah, area. In 1949 he joined the staff of Geneva Steel Co. as geological engineer in the raw materials dept. and served nearly three years, largely in the field, examining and exploring raw materials vital to the steelmaking industry. It was early in 1952 that he joined Bear Creek Mining Co. when Kennecott undertook an extensive exploration program.

On the occasion of the crash, Bill was on his way to keep an appointment on company business and to attend the meetings of the AIME and American Mining Congress. Bill was a Director of the Colorado Section of the AIME; area director of the Missouri School of Mines Alumni Assn.; member of the Utah Geological Society; and the Society of Economic Geologists.

He leaves behind him his wife, Lorraine, and three children, Carolyn, Billie, and Robert. He is also survived by his parents, Mr. and Mrs. Alonzo Burgin, a sister, and three brothers in Springfield, Mo., and a sister in Denver. He is also survived by his wife's parents, Mr. and Mrs. J. J. Beeson. Bill worked as a consulting mining geologist with Mr. Beeson and his close association with him through the years added to his professional know-how.

Bill's warm personality, his personal integrity, his concise thinking,

Necrology

Date of Election	Name	Date of Death
1948	Carl L. Alt	Unknown
1951	J. W. Bahen	Nov. 11, 1955
1929	Burt B. Brewster	Oct. 29, 1955
1928	J. H. Colville	Oct. 24, 1955
1951	V. A. Giesey	Nov. 5, 1955
1948	C. D. Huffine	Nov. 28, 1955
1946	H. V. Lauer	July 1955
1915	George A. Macready	Nov. 10, 1955
1942	H. B. Makin	Oct. 12, 1955
1953	J. L. Miller	Sept. 18, 1955
1901	F. L. Morris	Oct. 28, 1955
1926	Walter J. Morris	Mar. 21, 1955
1950	Roy R. Nissley	July 30, 1955
1920	Fraser D. Reid	Sept. 22, 1955
1950	Adron I. Rush	Aug. 14, 1955
1928	A. M. Tweedt	Nov. 23, 1955
1924	S. M. Thompson	Feb. 15, 1955
1948	C. B. Willmore	October 1955
1912	Clarence A. Wright	June 10, 1955

and new ideas in the geologic field will be greatly missed by his many associates and friends.

Charles A. Chase
An Appreciation by
J. D. Harlan

Charles A. Chase (Legion of Honor Member 1900) of the State of Colorado died Aug. 31, 1955 at near the age of 79. The following is a tribute by a mine operator who had his start with Chase in Telluride, Colo., almost 50 years ago and who retained his friendship thence throughout the latter's life. He was educated at the University of Colorado, was a member of AIME for 55 years, and was frequently honored in mining circles in the State of Colorado.

Under the guidance and with the sympathetic understanding of Arthur Winslow, the astute founder, Chase managed the Liberty Bell Gold mine through most of a productive period of nearly 25 years. With gold at the then prevailing value of $20.67 per oz the average net mint and smelter return was a little less than $7 per ton of ore milled and the profit from some 2,370,000 tons approached $3 million, a masterly accomplishment under the rugged circumstances of the operation.

As a rule the mines of that region were at about 12,000 elevation and connected with mills in the basin by aerial tramway and by steep roads that were not much more than pack-trails. To add to the problems of management, crushing snowslides and devastating campfires all too often took their toll. Labor was mostly from Europe and had to be trained at the job. Early in Chase's career a remnant of a group of anarchists that had created a reign of terror and lawlessness in Colorado and Idaho came to its end in the San Juan region but not before a mine manager had been murdered and another blasted out of his home. In such atmosphere Charles Chase operated and he and Mrs. Chase began the rearing of a family of three sons and a daughter who became a comfort and credit to their parents.

The comparatively low grade Liberty Bell mine was contemporary with the well managed Tom Boy; the rich Camp-Bird at Ouray; the famous Silver Lake of the Stoibers at Silverton; and the glamorous Smuggler-Union at Pandora. Notwithstanding the rugged and often disheartening operating conditions and the more favorable positions of neighbor-operators, Charles Chase stuck closely to the task, improved mine method and equipment, kept abreast of betterments in milling practice, never lost sight of the cost factor, and managed his low grade mine to an outstanding success.

He believed that orebodies were created by the same Great Architect that created man and he had the same love for and faith in them that he had in his fellow man. When he might have been thinking of easing up his professional life he envisioned the possibility of another Liberty Bell in a group of mines at Silverton and moved to that isolated region to equip and manage the second and last major undertaking of his career. There he lived and struggled against even greater odds than at Liberty Bell. The terrain was equally rugged, the ore of lower average value, and eventually conditions in general inflated costs without compensating increase in value of ore. Even so, Chase's managing performance at Silverton was even more remarkable than in Telluride because economic conditions were more variable and other odds much greater.

Notwithstanding adversity and disappointment Charles Chase continued courageous and honest, never ceased giving his all toward creation of wealth in his beloved State of Colorado as well as stability in his mining community, and ever remained dignified, tolerant, humble, and modest—a really great man. Surely for him there will be a gold mine in the sky.

James Richard Gill (Member 1932) died May 28, 1955. Mr. Gill was chief engineer, Falconbridge Nickel Mines Ltd., Falconbridge Ont. He was born in Orillia, Ont., in 1891 and graduated from the University of Toronto with a B.A.Sc. in

MEMBERSHIP

Proposed for Membership
Mining Branch, AIME

Total AIME membership on Nov. 30, 1955 was 23,526; in addition 2284 Student Associates were enrolled.

ADMISSIONS COMMITTEE

P. D. Wilson, Chairman; F. A. Ayer, Vice-Chairman; A. C. Brinker, R. H. Dickson, T. D. Jones, F. T. Hanson, Sidney Rolle, O. B. J. Fraser, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld, R. B. Caples, F. W. McQuiston, Jr., A. R. Lytle, H. R. Wheeler, L. P. Warriner, J. H. Scaff.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

George E. Alter, Jr., Martinsburg, W. Va.
Robert A. Baxter, Golden, Colo.
Arthur F. Beacher, Frackville, Pa.
Robert B. Botsford, Dallas, Pa.
Peter G. Braham, Kalgoorlie, Western Australia
James B. Chaney, Bellaire, Texas
Archibald R. Dunning, Strasburg, Va.
Tobias Eichler, Wilkes-Barre, Pa.
Harry Ellswood, Dundee, Wilkes-Barre, Pa.
Edward Futterer, Jr., Blind River, Ont.
Terry S. Gamble, Weston, Ont.
John J. Gillis, Norwood, Mass.
Albert A. Guffey, Bartow, Fla.
Dorr N. Holloway, Sleetmute, Alaska
Glenn L. King, Newgulf, Texas
Clair M. Kunkel, Bishop, Calif.
Paul A. Lancaster, Kings Mt., N. C.
Walter R. Lawrenz, Hurley, N. M.
Robert M. Mackintosh, Kimberly, Nev.
LeRoy T. McGuire, Salt Lake City
Henry E. Mohr, Bessemer, Ala.
Forest H. Neely, Philadelphia
William L. Newman, Grand Junction, Colo.
George F. Pettinos, Jr., Wynnewood, Montgomery County, Pa.
Stanislaw J. Poborski, College, Alaska
Carl B. Richardson, Tucson, Ariz.
George M. Seiler, Ashland, Pa.
Bert Serassio, Lark, Utah
Harvey A. Shiffer, Los Angeles
Harold E. Shomper, Shamokin, Pa.
Paul C. Simmons, Morenci, Ariz.
A. Leonard Smith, American Embassy (USOM), Amman, Jordan
Bennett L. Smith, New Brunswick, N. J.
Joe B. Stanley, Morenci, Ariz.
Ray P. Taylor, Starke, Fla.
Peter G. Woods, Jr., Albuquerque, N. M.
Marcus L. Hovland, Hibbing, Minn.
Lawrence F. Hurley, Pittsburg, Kan.
Max E. Kofford, Grand Canyon, Ariz.
Robert K. Linn, Glendale, Calif.
Henry J. Moore, II, Grand Junction, Colo.
David C. Scull, Washington, D. C.
Morton D. Strassberg, Grand Junction, Colo.
Leslie B. Thompson, Sanford, Fla.
Herbert J. Toohey, Albuquerque, N. M.
LeRoy F. Van Scoyk, San Manuel, Ariz.
Jay R. Ziegler, St. Paul

REINSTATEMENTS

Members

Everett P. Carman, McLean, Va.
Charles H. Dodge, Pittsburgh
Robert F. Lyman, Crooked Creek, Alaska

Associate Members

James W. Alewine, Houston
Guerdon L. Anderson, Stambaugh, Mich.
Philip D. Anderson, Morenci, Ariz.
John G. Bachner, Anchorage, Alaska
Robert A. L. Black, Johannesburg, South Africa
Patrick V. Gallagher, Cleveland
James N. Harris, North Birmingham, Ala.
Allan J. Hersey, College, Alaska
Theodore A. Knight, Silver Bell, Ariz.
John W. Losse, Jr., Salt Lake City
DeOtis L. Marlett, Rolling Hills, Calif.
Virgil O. McCollum, Carlsbad, N. M.
Albert O. Nelson, Duluth
Roswell D. Schenck, Carlsbad, N. M.
John H. Taylor, Jr., Phoenix, Ariz.

Junior Members

William F. Attwood, College, Alaska
Juan R. Ayza, Lima, Peru
William E. Bales, Bakersfield, Calif.
Peter Beaumont, Otu. (Via Medellin), Colombia
David M. Bennett, Cedar City, Utah
James R. Bingel, Denver
Robert Bowman, Lakewood, Colo.
Augusto Chian, Lima, Peru
Glendon E. Collins, Albuquerque, N. M.
Robert C. Dickinson, Grand Junction, Colo.
William R. Ellis, Moab, Utah
Raymond A. Foos, Kenmore, N. Y.

Junior to Member

Douglas H. Elliott, Casper, Wyo.
Donald R. Ferguson, Grants, N. M.
Eric W. Johnson, Schumacher, Ont.

Student to Member

Richard N. Appling, Jr., Spokane, Wash.
Carl R. Adelmann, Jr., Palo Alto, Calif.
Robert O. Giroux, Ray, Ariz.
Michael A. Zappia, San Manuel, Ariz.

Junior to Associate

Merlynn O. Anderson, Price, Utah

Student to Associate

Charles E. Robertson, Carlsbad, N. M.

Student to Junior

James D. Lowell, Denver

CHANGE OF STATUS

Associate to Member

Donald C. Hardin, Jr., Stamford, Conn.
Fred H. Howell, Silver City, N. M.
Donald H. Johnson, Golden, Colo.
Kenneth B. Platt, Keystone Heights, Fla.
Theophilus M. Rizzi, Lead, S. D.
William T. Rule, Cave-in-Rock, Ill.
Rex Tario, Lead, S. D.
Roberts M. Wallace, Grand Junction, Colo.
Clarence H. Sleeman, Virginia, Minn.

Junior to Member

Richard C. Barr, Morenci, Ariz.
Robert H. Holgers, Montreal, Wis.
William R. Hudspeth, Jr., Kings Mountain, N. C.

1914. Mr. Gill was a land surveyor until 1917 when he joined British America Nickel Corp. Ltd. He was an engineer on construction and design, a smelter shift foreman, and then assistant smelter superintendent for this company. After returning to surveying in 1924, Mr. Gill joined Falconbridge in 1928 as smelter superintendent in charge of design, construction, and operation. He was a member of the Canadian Institute of Mining and Metallurgy.

Lincoln Kilbourne (Member 1952) died on Oct. 5, 1955, following a heart attack suffered two days earlier. Mr. Kilbourne was general manager of sales, Industrial Div., Jeffrey Mfg. Co., Columbus, Ohio, and had been with the company for nearly 22 years. He was born in Columbus in 1911. After graduating from Ohio State University in 1933 with a B.S. in ceramic engineering, Mr. Kilbourne joined Jeffrey in the plant and sales offices, Columbus. From 1941 to 1946 he served in the Army Air Force, attaining the rank of lieutenant colonel, Deputy Chief of Staff 315th Bomb Wing. He then rejoined Jeffrey as district manager, Jacksonville, Fla.

Dale L. Pitt (Member 1916) died Sept. 10, 1955. He was managing director of Silbak Premier Mines Ltd., Vancouver, B. C. Mr. Pitt was born in Salt Lake City in 1884. He graduated in 1907 from Utah School of Mines with a B.S. in mining engineering. Mr. Pitt gained his early experience in various companies, including B. F. Tibby Co., Salt Lake City; Federal Lead Co., Flat River, Mo.; and Tacoma Smelting Co., Tacoma, Wash. He was manager for Premier Gold Mining Co. at Hyder, Alaska; Premier, B. C.; and Cue, Western Australia. Mr. Pitt was also general manager, Big Bell Mines Ltd., Western Australia.

Herbert William Rich (Member 1952) died in Front Royal, Va., on Oct. 5, 1955, of a cerebral hemorrhage. Mr. Rich was vice president of operations for both the Riverton and Dominion Minerals Divisions of the Riverton Lime & Stone Co. Inc., Riverton, Va. He was born in Bayonne, N. J. in 1904. After graduating from Lehigh University in 1926, Mr. Rich joined Northern Peru Mining & Smelting Co., Samne, Peru. From 1929 to 1933 he was sales engineer for Worthington Pump & Machinery Corp., Harrison, N. J. Mr. Rich then became quarry superintendent, U. S. Gypsum Co., Chicago. In 1941 he went to Penn-Dixie Cement Corp., Nazareth, Pa., and during the next eight years was plant superintendent, division superintendent, and operations assistant. In 1953 Mr. Rich joined the Riverton Lime & Stone Co. as a vice president in charge of operations, Dominion Minerals Div., Piney River, Va.

GODFREY B. WALKER
Metallurgical Consultant
Mineral Dressing & Extractive Metallurgy
Heavy Media a Specialty
27 Lockwood Drive Old Greenwich, Conn.

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Coming Events

Jan. 9, AIME, Boston Section. Speaker: AIME President H. DeWitt Smith.

Jan. 9, Minnesota Section, annual meeting, 10:00 am, Shrine Auditorium, Duluth. Headquarters, Hotel Duluth.

Jan. 11, AIME, Connecticut Section, New Haven. Students' night. Speaker: AIME President H. DeWitt Smith.

Jan. 13, AIME, Reno, Nev., Subsection, El Cortez Hotel, Blue Room, Reno, 12:00 m. Installation of 1956 officers.

Jan. 14, AIME, New Mexico Section, Fez Club, 1956 business meeting. Guest: AIME Director C. R. Kuzell.

Jan. 20, AIME, Philadelphia Section. Speaker: AIME President H. DeWitt Smith.

Jan. 20, AIME, St. Louis Section, Hotel York, 6:00 pm. Speaker: F. A. Forward, "New Boundaries in Chemical Metallurgy."

Jan. 26-27, Engineers Joint Council General Assembly, Statler Hotel, New York.

Feb. 2, AIME, Utah Uranium Subsection, 7:30 pm, Arches Cafe, Moab, Utah.

Feb. 2-3, Governor's Industrial Safety Conference, 6th annual statewide meeting, Fairmont Hotel. San Francisco. Mineral Extraction Section meets Feb. 2 and 3 at 1:00 pm.

Feb. 6-9, Industrial Ventilation Conference, Kellogg Center, East Lansing, Mich. Sponsored by Div. of Occupational Health, Michigan Dept. of Health, and School of Engineering, Michigan State University.

Feb. 20-23, AIME, Annual Meeting, Statler and New Yorker hotels, New York.

Feb. 27-29, Rocky Mountain Section, American Assn. of Petroleum Geologists, 6th annual convention, Municipal Auditorium Annex, Denver.

Mar. 28-31, AIME, Nevada Section, Reno.

Mar. 28-31, Cordilleran Section, Geological Society of America, convention, Reno, Nev.

April 6, Pennsylvania Anthracite Section, Necho Allen Hotel, Pottsville, Pa. John Cipyak will speak on "Machine Accounting as Applied to Mining Industry."

Apr. 9-11, AIME, Open Hearth and Blast Furnace Conferences, Netherland Plaza Hotel, Cincinnati.

Apr. 9-11, Canadian Institute of Mining and Metallurgy, annual meeting, Chateau Frontenac, Quebec City.

Apr. 23-25, Symposium on Rock Mechanics, Colorado School of Mines, Golden, Colo.

Apr. 23-26, American Assn. of Petroleum Geologists, Conrad Hilton Hotel, Chicago.

May 3-5, AIME, Pacific Northwest Regional Conference, Olympic Hotel, Seattle.

May 7-9, American Mining Congress, Coal Convention, Netherland Plaza Hotel, Cincinnati.

Sept. 26-28, Rocky Mountain Minerals Conference. Salt Lake City.

Oct. 1-4, American Mining Congress, Mining Show, Shrine Auditorium, Los Angeles.

Oct. 8-10, AIME, Institute of Metals Div., Allerton Hotel, Cleveland.

Oct. 14-17, AIME, Petroleum Branch, Biltmore Hotel, Los Angeles.

Feb. 24-28, 1957, AIME Annual Meeting. Roosevelt and Jung hotels, New Orleans.

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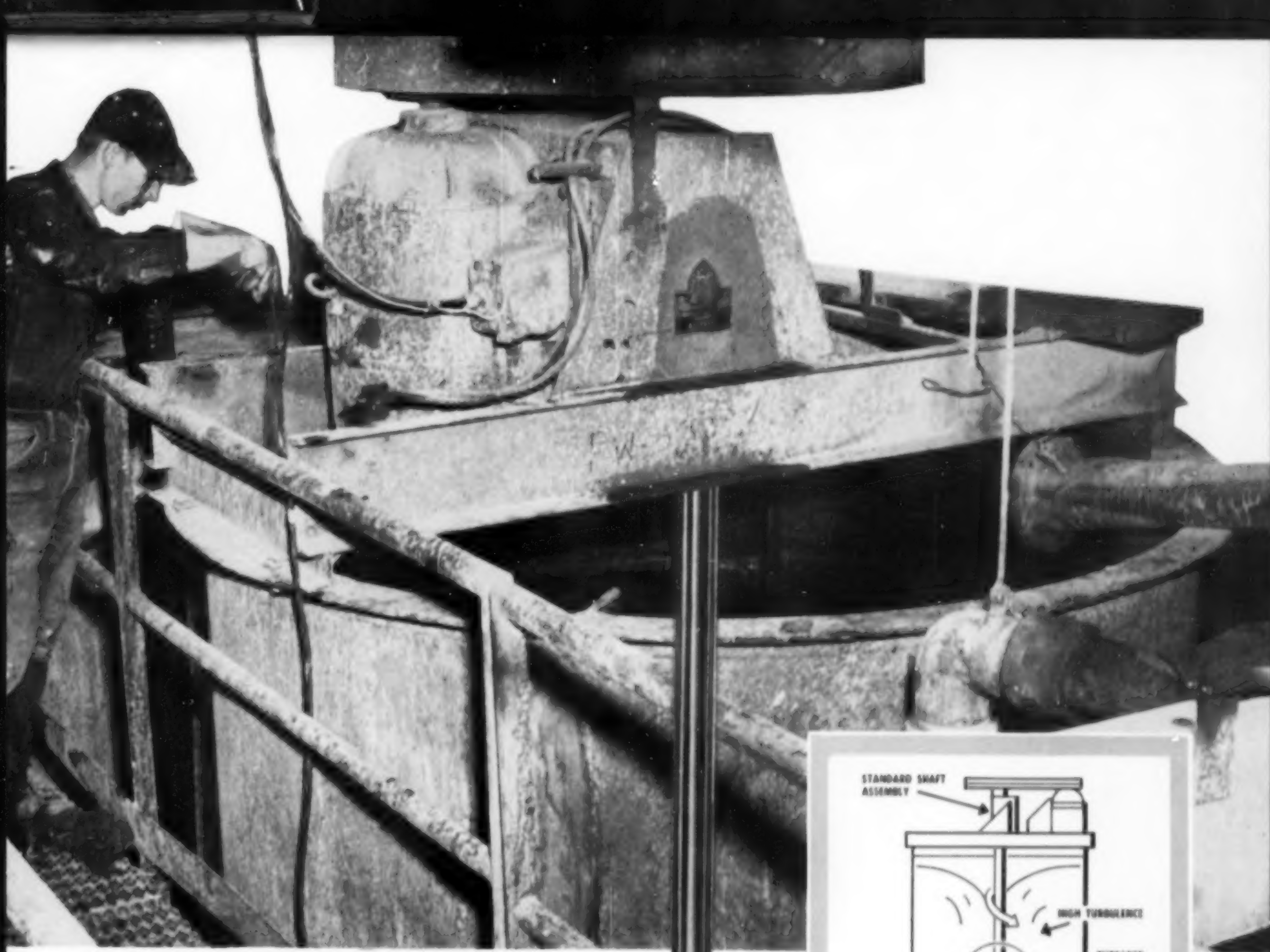

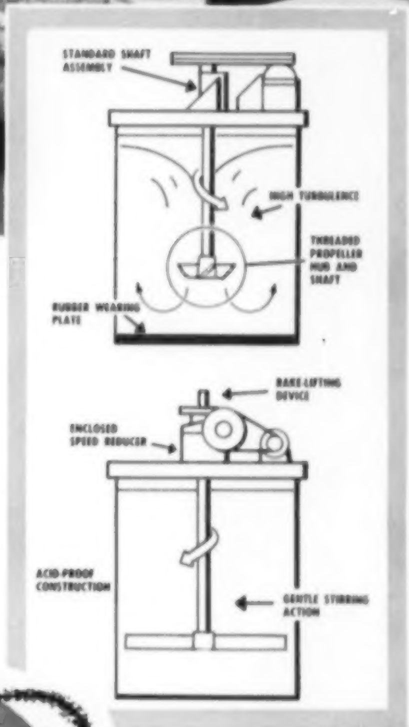

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